A SURVEY OF THE CONDITION OF STREAMS IN THE PRIMARY REGION OF MOUNTAINTOP MINING/VALLEY FILL COAL MINING

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TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
CHIA	Cumulative Hydrologic Impacts Assessment
CPC	Climate Precipitation Center
EMAP	Environmental Monitoring and Assessment Program
EIS	Environmental Impact Statement
EPT	Ephemeroptera, Plecoptera, Trichoptera
HBI	Hilsenhoff Biotic Index
KYDW	Kentucky Division of Water
MDDNR	Maryland Department of Natural Resources
MTM/VF	Mountaintop Mining/Valley Fill
MTR/VF	Mountaintop Removal/Valley Fill
NDMC	National Drought Mitigation Center
NERL	National Exposure Research Laboratory
NWS	National Weather Service
OMR	Office of Mining Resources
ORD	Office of Research and Development
OSM	Office of Surface Mining
OWR	Office of Water Resources
PEIS	Programmatic Environmental Impact Statement
RBP	Rapid Bioassessment Protocol
RMSE	Root Mean Square Error

SCI	Stream Condition Index
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WVDEP	West Virginia Division of Environmental Protection

1.0 EXECUTIVE SUMMARY

A typical mountaintop mining/valley fill (MTM/VF) mining operation in the Appalachian coal fields removes overburden and interburden material to facilitate the extraction of coal. Excess spoils are often placed in adjacent valleys containing first and second order streams. The effect of these mining operations on the biological condition of reaches downstream of the fills is uncertain. This study was designed to provide information on the biological condition of streams downstream of a variety of MTM/VF activities.

This study considered three objectives:

1. Characterize and compare conditions in three classes of streams: 1) streams that are not mined (termed "unmined"); 2) streams in mined areas with valley fills (termed "filled"); and 3) streams in mined areas without valley fills (termed "mined").

2. Characterize conditions and describe any cumulative impacts that can be detected in streams downstream of multiple fills.

3. Characterize conditions in sediment control structures (ditches) on MTM/VF operations.

The original objectives describe three classes (unmined, filled and mined), but this final report discusses four classes (unmined, filled, filled/residential and mined). Preliminary analysis of the data indicated that streams with both valley fills and residences in their watersheds appeared to be more impaired than streams with only valley fills (no residences) in their watersheds. Since we were interested in characterizing the effects of valley fills on streams, we separated those sites with both valley fills and residences in their watersheds into a new category described as "filled/residential". There were six sites that had both valley fills and multiple residences or small communities in their watersheds. To be consistent, we also identified two sites in the mined class that had residences in their watersheds, described as "mined/residential". Since there were only two of these sites, they were not included as a separate group in analysis. There was one site in a sediment control structure that was not included in the analysis of classes since there was only one of these sites, and the site habitat was more typical of ponds and wetlands than natural streams.

In this study, we evaluated benthic macroinvertebrate assemblage data, physical stream habitat assessments, quantitative estimates of substrate size, and limited field chemical/physical parameters. Please contact the authors if you would like electronic files of the raw data.

1.1 Objective 1: Summary of Findings

Biological conditions at the unmined sites were comparable to a broad state-wide wadeable streams reference condition developed by the West Virginia Department of Environmental Protection (WVDEP). This reference condition was based on a data set of 1268 benthic samples collected from 1996 to 1998. This reference condition defines condition categories of very good,

good, fair, poor and very poor based on Stream Condition Index (SCI) scores. Scores in the fair, poor and very poor range are impaired relative to the reference condition.

Biological conditions at the unmined sites were also comparable to conditions in a smaller set of WVDEP reference sites (7 sites) which are located in the primary region of MTM/VF coal mining. These sites were sampled in 1997 and 1998 by the WVDEP.

Biological conditions in the unmined sites generally represented a gradient of conditions from good to very good, based on the WVDEP SCI scores. These sites are primarily forested, with no residences in the watersheds. One site scored in the high-end of the fair range in the summer of 1999, one site scored in the poor range in the fall of 1999, and one site scored in the high-end of the fair range in the winter of 2000. We believe these sites scored lower primarily because the drought and lower flows impeded our ability to collect a representative sample. We observed no other changes at these monitoring sites that could account for the changes in the condition of the streams, other than the low flows. When these sites were sampled in later index periods, they scored in the good or very good range.

Biological conditions in the mined sites generally represented very good conditions, although a few sites did score in the good and poor range. We believe that the one site that scored in the poor range is naturally flow-limited even during periods of normal flow. We believe this site is ephemeral and only flows in response to precipitation events and snow melt. The other mined sites generally have only a small amount of mining activity in their watersheds. In fact, many of these sites were believed to be in the unmined class prior to the first round of sampling and ground truthing.

Biological conditions in the filled sites generally represented a gradient of conditions from poor to very good. One site scored in the very poor range in the spring of 2000. Over the five seasons, filled sites scored in the fair range more than half of the time. However, over a third of the time, filled sites scored in the good or very good range over the five seasons. We believe water quality explains the wide gradient in biological condition at the filled sites. The filled sites that scored in the good and very good range had better water quality, as indicated by lower median conductivity at these sites. The filled sites that scored in the fair, poor and very poor ranges had degraded water quality, as indicated by elevated median conductivity at these sites (see figures 86 and 87).

Biological conditions in the filled/residential sites (filled sites that also have residences in their watersheds) represented a gradient of conditions from poor to fair. Over the five seasons, filled/residential sites scored in the poor range more than half of the time. The remainder of the filled/residential sites scored in the fair range. No sites in the filled/residential class scored in the good or very good range. All sites in the filled/residential class had elevated median conductivities.

In general, the filled and filled/residential classes had substantially higher median conductivity than the unmined and mined classes. It is important to note that the filled sites generally had comparable or higher conductivity than the filled/residential sites within a watershed, indicating that the probable cause of the increase in the total dissolved solids at the filled/residential sites was the mining activity upstream rather than the residences. Unfortunately, there are no aquatic life criteria for conductivity or total dissolved solids.

Biological conditions in the filled and filled/residential classes were substantially different from conditions in the unmined class and were impaired relative to conditions in the unmined class, based on the WV SCI scores.

The filled/residential class was the most impaired class. The causes of impairment in this class could include several stressors (e.g. the valley fills, the residences, roads). It is impossible to apportion the impairment in this class to specific causes with the available data.

The general patterns of stream biological condition presented in the previous paragraphs were clear in all three seasons that have complete data sets (spring 1999, winter 2000 and spring 2000). By complete, we mean that the unmined sites could be sampled.

An independent benthic data set collected at a subset of our sites in the winter 2000 season by Potesta and Associates, Inc. for Arch Coal supports our conclusions. Our analysis of the only complete data set provided by Potesta and Associates (Winter 2000) indicated that the sites in the filled and filled/residential classes were biologically impaired relative to the unmined sites (Green and Passmore 2000). The filled/residential class was the most impaired class.

Over the course of this study, pH, temperature and dissolved oxygen measurements were usually within the bounds of the aquatic life criteria for these parameters. (The only violation was measured in the sediment control structure). Acidity and low dissolved oxygen do not appear to be limiting the aquatic life in these streams. Temperature was fairly comparable within the four classes. Dissolved oxygen, pH and temperature can all vary during the day and through the seasons. The grab samples for these parameters may not be representative of long term water quality at these sites and should be treated with some caution.

It is not uncommon for streams to meet or exceed ambient water quality criteria but they do not fully support aquatic life. Biological communities respond to and integrate a wide variety of chemical, physical and biological factors and stressors. Ohio EPA (Yoder 1995) found that out of 645 waterbody segments analyzed, biological impairment was evident in 49.8% of the cases where no impairments of chemical water quality criteria were observed. In addition, as in this case, often only a few selected chemical parameters are measured, and they only offer a snap shot of the long term water quality in a stream..

The Rapid Bioassessment Protocols habitat assessment data did not indicate substantial differences between the stream classes. The habitat in the filled class and the filled/residential class was slightly degraded relative to the unmined class. Individual sites in the filled and filled/residential classes had degraded habitat and excessive sediment deposition.

In general, the substrate characteristics of the filled, filled/residential, and mined classes were not substantially different from the unmined class. Our data did not indicate excessive fines in the filled or the filled/residential classes as a whole, however, there were specific sites within these classes with substantially higher percentages of sand and fines compared to the unmined class. It should be noted that many of the filled sites were established in first and second order watersheds in order to limit the potential stressors in the watershed to the valley fills. Our data indicate that the valley fills and associated mining activity did not cause excessive sediment deposition in the upper reaches of these watersheds. It would not be appropriate to extrapolate our conclusions to reaches farther downstream in these watersheds or to larger order streams.

Correlations between the benthic metrics and selected physical and chemical variables indicate that the strongest and most significant associations were between biological condition and conductivity. Physical habitat variables were more weakly correlated with biological condition and some of these associations were not significant. Water quality appears to be the major factor limiting the benthos in the impaired streams.

Several unmined sites could not be sampled for benthos in the summer and fall of 1999 due to the drought. These sites were either dry or did not have adequate flow to collect a representative sample in these seasons. All of the unmined sites could be sampled by the winter 2000 sampling period and the conditions at most of the unmined sites scored in the good to very good range in the winter of 2000 (including the one unmined site that scored in the high-end of the fair range in the summer of 1999 and the one unmined site that scored in the poor range in the fall of 1999). One unmined site scored in the high-end of the fair range in the winter of 2000. All of the unmined sites scored in the very good range in the spring of 2000.

Most of the filled sites could be sampled for benthos in the summer and fall of 1999. We believe a probable cause for the sustained flows in the filled streams during the drought could be decreased evapotranspiration in those watersheds due to the replacement of forested cover with grassland cover on the mined areas. Decreased evapotranspiration has been found to increase streamflow (see section 2.3 for a more detailed discussion).

Our field observations and our data indicate that surface flow in the filled sites during the drought was greater than surface flow in the unmined streams. Some may conclude that this is a positive impact of mountaintop mining and valley fills, as this could result in perennial flow and hence benefit aquatic life. This position assumes two points: 1) the water quality in the filled streams does not change and 2) perennial flow is required for support of aquatic life. However, our data indicate that at many of the filled sites, the water quality was degraded due to the mining activity. So, even though there was more flow at the filled sites, the water quality was degraded. Furthermore, our data and the scientific literature indicate that benthic macroinvertebrates are clearly able to survive periods of low or no surface flow. In addition, some authors indicate that some benthic species are only found in intermittent flow regimes. Clearly, perennial flow regimes are not required to support diverse and abundant assemblages of macroinvertebrates (see section 5.1 for a more detailed discussion).

1.2 Objective 2: Summary of Findings

We used the WVDEP SCI scores to determine overall differences in biological condition upstream and downstream of four MTM/VF operations. A monitoring site was established as the upstream control, and a site was established as the downstream control. (We did not call these sites "reference" sites because in many cases, they were not comparable to reference conditions.) This was a difficult objective to explore. In three of the cases (Mud River, Spruce Fork, and Island Creek), there were potential stressors not related to the MTM/VF operations of interest located upstream of the upstream control site and in between the upstream and downstream control sites. The upstream control sites in the Mud River and in Spruce Fork were impaired and the upstream control site in Cow Creek (Island Creek) was not impaired. In one watershed (Clear Fork), this objective could not even be explored because several of the headwater streams in the watershed had been filled by the MTM/VF operation. The only substantial differences between the upstream and downstream sites were observed in Cow Creek (Island Creek). Biological conditions were much worse at the downstream site compared to the upstream site. The observed impairment could be caused by several stressors, including mining and residential land use.

1.3 Objective 3: Summary of Findings

We considered several sediment control structures as candidate monitoring sites. However, many of the sites were not reconstructed streams, but ponds or dry ditches filled with boulder-sized rip-rap. Only one sediment control structure was identified as having flowing water that could be sampled. Since only one such site was sampled, this study provides only limited information to characterize conditions in sediment control structures on MTM/VF operations.

Site MT24, located in a sediment control ditch on a surface mine, was more degraded than any site sampled in the study. The SCI score at this site was in the poor or very poor range over all five seasons. The entire drainage area of this site has been disturbed by mining. The ditch does not represent natural stream habitat. This was also the only site in the study where we observed a violation of a water quality criterion. In the summer 1999 index period, we measured a dissolved oxygen concentration of 3.6 mg/l, which is less than the required minimum of 5 mg/l.

2.0 INTRODUCTION

2.1 The Primary Region of Mountaintop Removal Coal Mining

The West Virginia Geological and Economic Survey has described the primary region of mountaintop removal coal mining in West Virginia (Fedorko and Blake 1998). They indicate that the majority of the mountaintop removal mines target the Coalburg coal zone and the overlying Stockton coal and associated riders (Kanawha Formation) and/or the "Block" coal zones of the overlying Allegheny Formation. The region encompassing the outcrop belt of these targeted zones includes portions of Lincoln, Wayne, Mingo, Logan, Boone, Wyoming, Raleigh, Kanawha, Fayette, Nicholas, Clay, Webster and Braxton counties.

The region lies in the Cumberland Mountains of the Central Appalachian Plateau (subecoregion 69d) (Woods et al 1999). Woods et al describe the physiography as being unglaciated, dissected hills and mountains with steep slopes and very narrow ridge tops. The geology is described as being Pennsylvania sandstone, siltstone, shale, and coal of the Pottsville Group and Allegheny Formation. The primary land use is forest with extensive coal mining, logging, and gas wells. Some livestock farms and scattered towns exist in the wider valleys. Most of the low-density residential land use is concentrated in the narrow valleys.

2.2 Monitoring Design and Rationale

This survey was designed to provide a synoptic description of stream conditions in five watersheds across the primary MTR/VF region, as defined by the West Virginia Geological and Economic Survey. These watersheds are Twentymile Creek of the Gauley River Basin, Island Creek and Mud River of the Guyandotte River Basin, and Clear Fork and Spruce Fork of the Coal River Basin (figures 1 and 2). Within each watershed, two arrays of streams were selected by staff familiar with the mining operations in the watershed (primarily WVDEP mining inspectors and the Streams Workgroup staff working on the PEIS). One stream array in each watershed was thought to be unmined. The other stream array in each watershed contained significant MTM/VF operations.

Since many characteristics of the candidate sites were largely unknown before the first field visit, it was impossible to correctly attribute sites prior to the first round of sampling. Some of the sites that were originally thought to be unmined had mining activity in their watersheds and were reclassified as mined. During field reconnaissance, it became apparent that the unmined sites were only in first and second order streams. There were no unmined sites in streams larger than second order. There was only a limited number of sites in the mined class, and the sites do not represent the full gradient of mined conditions. Many of the mined sites have only a small amount of historical mining activity in their watersheds.

The sites in the filled and filled/residential classes represent a gradient of number and size of fills, age of fills, and stream orders. We believe we have accurate data on the number of fills upstream of the sampling sites. However, the number of fills does not correlate to the total area of the watershed disturbed by mining or the area filled because of the wide variation in the size of the fills. We do not have accurate or detailed information on the size, age, or other characteristics of the fills. Therefore, we did not explore correlations between stream condition and fill characteristics (type, size, age, etc).

Preliminary analysis of the data indicated that the sites with valley fills and residences in their watersheds appeared to be more impaired than those sites with only valley fills in their watersheds. Therefore, in order to better characterize any impairment found in the filled class of sites, we created a new class of sites called filled/residential. Sites with valley fills and residences in their watersheds were put into this class.

Thirty-seven (37) benthic sampling sites were chosen from a larger pool of candidate sampling sites (a total of 127 sites) during the first sampling event in late April and early May of 1999. The thirty-seven (37) sites include nine (9) unmined sites, fifteen (15) sites with a valley fill or fills upstream of the sampling location, six (6) sites with both valley fills and residences upstream of the sampling location, and four (4) sites with some other sort of past mining activity upstream (other than valley fills) and no residences. In addition, two sites with past mining activity and residences in their watersheds and one site in a sediment control structure were chosen for monitoring. The nine unmined sites did not have any residences in the watershed upstream of the sampling site and were primarily forested. A list of the sampling sites and several attributes for the sampling sites are included in Appendix 1 (e.g. locational information, EIS class, stream order, watershed size).

In the spring of 2000, two more sites were added. One site was an unmined site which was added to provide a unmined reference site closer to the filled sites in the Island Creek watershed. The other site was located in the Mud River watershed and was added to provide another mined site to the small class of mined sites.

We considered several sediment control structures as candidate monitoring sites. However, many of the sites were not reconstructed streams, but ponds or dry ditches filled with boulder-sized rip-rap. Only one sediment control structure was identified as having flowing water and could be sampled. Since only one such site was sampled, this study provides only limited information to characterize conditions in sediment control structures on MTM/VF operations.

2.3 Effects of the Drought

The region of MTM/VF coal mining in West Virginia suffered periods of prolonged dryness and drought in 1998 and 1999. See Appendix 6 for a detailed discussion and documentation of the drought.

The drought clearly impacted our ability to effectively sample the streams. In the summer and fall of 1999 we could not collect representative invertebrate samples from several streams due to very low or no flows. Most of the flow-limited streams were unmined streams. Therefore, the summer and fall 1999 data sets are incomplete and provide limited data to determine the biological condition of the filled sites relative to unmined sites. For this report, we relied on the spring 1999, winter 2000 and spring 2000 datasets to draw conclusions about the biological conditions of streams and stream classes.

Our data indicate that when these streams could be effectively sampled, following the low flow conditions, they were in good or very good biological condition. Benthic invertebrates are clearly able to survive periods of low or no surface flow (see section 5.1 for a more detailed discussion).

Clearly, the drought and the decreased precipitation affected stream flow. Stream flow can also be affected by many characteristics of the watershed including porosity and permeability, infiltration, runoff, evapotranspiration, groundwater flow, etc (Farndon 1994). Mountaintop mining and valley fills alter many of these parameters. Evapotranspiration is the major use of water in all but extremely humid, cool climates. Furthermore, the majority of the water loss due to evapotranspiration takes place during the summer months. If evapotranspiration is reduced, then runoff or ground-water infiltration or both could increase. Studies have shown that basin runoff from a forested watershed increased following the timbering of a watershed. In some areas of the humid eastern United States, which were originally in forest, as old fields reconverted to forests, there was a concomitant decrease in streamflow. Conversion of one plant cover to another can also affect the evapotranspiration rate. In arid Arizona, the conversion of a plot of land formerly covered with chaparral to grasses resulted in streamflow increases of several hundred percent (Fetter 1988). Clearly, at the filled sites, the evapotranspiration rates in the watershed could be affected by the changes in vegetative cover (from forest lands to grasslands) associated with the mining activity.

2.4 Monitoring Parameters and Their Frequency of Collection

Streams were sampled in five seasons (spring 1999 (late April and early May), summer 1999 (late July and early August), fall 1999 (late October and early November), winter 2000 (late January and early February) and spring 2000 (late April and early May)) for a suite of biological, chemical/physical and physical habitat measures, when adequate flows allowed. Every parameter was not sampled each season (see below).

Several of the streams could not be sampled during the summer and fall 1999 sampling seasons, as the streams were either completely dry or the flow was too limited to allow benthic sampling. In this study we define “flow limited” streams as those streams with some flow, but with insufficient flow to effectively carry organisms and debris into the sampling net.

Monitoring parameters, sampling methods and their frequency of collection are described in depth in the Quality Assurance Project Plan for this study (Green et al 1999). These methods are summarized here. In the field, a study reach of 100 meters of longitudinal stream length was established for sampling sites with a mean wetted width of 2.5 meters or smaller. At some of the larger sites, it was necessary to sample a longer reach for the substrate size characterization protocol. At these sites, a reach length of forty times the wetted width was used, up to a maximum of 500 meters. A site identification section and sketch of each site was completed in the field once during the study period, unless conditions changed and then another sketch and description were completed to reflect those changes. Upstream and downstream photos of each sampling site were taken during each visit.

The benthic sampling site was located at the mid point of the reach unless the site-specific circumstances required that the reach be moved upstream or downstream to avoid tributary effects, bridges or fords. Macroinvertebrate were sampled using the USEPA Rapid Bioassessment Protocols (RBP) single habitat sampling protocol (Barbour et al 1999). The sample was collected in riffle habitat only. A 0.5 meter wide, 595 micron rectangular sampling net was used to collect organisms in a 0.25 square meter area upstream of the net. Four samples, each representing 0.25 square meters of riffle habitat, were composited. The total area sampled for each sample was approximately 1 square meter.

About 25% of the samples were sampled in replicate to provide an estimate of within season/within site variability. Replicates samples were collected at the same site, at the same time, and usually in adjacent locations within the same riffle. In some cases it was necessary to collect the replicate sample in an adjacent riffle. These replicates were highly correlated to each other (Appendix 5). Where replicates were collected, only the first sample collected was used when graphing the data and in descriptive and statistical analyses of the data.

The RBP single habitat protocol was slightly modified to collect 1 square meter of substrate rather than 2 square meters. This modification was made because many of the streams sampled were small. It would have been difficult to sample 2 square meters of riffle habitat in some of the streams in each of the four seasons. Because of the drought, we felt that a smaller sampling area would make it more likely that we could collect comparable samples over the five seasons.

We believe the 1 square meter sampling area provided sufficient sampling area to collect a representative sample. This finding is based on a comparison of our benthic data to the WVDEP reference condition. Samples collected by USEPA from unmined sites using the 1 square meter sampling area were of comparable condition to samples collected by WVDEP at reference sites in the MTM/VF region using the 2 square meter sampling area, based on the WVDEP Stream Condition Index (SCI) scores. The conditions of the unmined streams sampled in this study were characterized as good or very good using the WVDEP SCI. Conditions of very good are highly comparable to the WVDEP reference condition (above the 25th percentile) and conditions of good are comparable to the below average reference sites (between the 5th and 25th percentiles). Clearly, if the unmined sites we sampled using the 1 square meter technique scored in the same condition class as the WVDEP reference sites sampled using the 2 square meter sampling technique, we collected a representative sample of the benthic assemblage which was comparable to the WVDEP reference condition.

Samples were preserved in 100% ethanol. In the laboratory, a 1/8th subsample was picked and the organisms were identified using published taxonomic references (Merritt and Cummins 1996, Peckarsky et al 1990, Pennak 1989, Stewart and Stark 1993, Westfall and May 1996, Wiggins 1998) to the family level, except for Oligochaeta (worms) and leeches which were identified at the class level. This subsampling method is a standard level of effort approach. Every sample was picked a second time by an independent picker. Pick error rates were recorded for every sample. All picking and identification was done in the USEPA Wheeling, WV laboratory. Benthic macroinvertebrate samples were collected at each site, in each season, provided there was sufficient flow for sampling.

The stream physical habitat was assessed using USEPA RBP protocols (Barbour et al 1999). The RBP habitat protocol rates 10 aspects of physical habitat on a scale of 1 to 20 for an overall maximum possible rating of 200. Parameters evaluated in the sampling reach include epifaunal substrate/available cover; embeddedness; velocity/depth regimes; sediment deposition; channel flow status; channel alteration; frequency of riffles; bank stability; bank vegetative protection; and riparian vegetation zone width. The habitat assessment was performed on the reach that encompassed the biological sampling site. Some parameters do require an observation of a broader area of the catchment other than the sampling reach.

Physical habitat evaluations were performed at all sites which were sampled for benthic macroinvertebrate in the fall of 1999. However, the flow at several of the sites was very low and these sites could not be sampled for benthos in the fall of 1999. Physical habitat evaluations were completed for these sites in the spring of 2000, when adequate flow was present to sample the benthic assemblage. The physical habitat evaluations performed at flowing sites in the fall of 1999 were reviewed in the field in the spring of 2000. Any changes from the fall of 1999 to the spring of 2000 were noted on the original sheet. For example, channel flow status and velocity depth regimes vary with flow, and many of these parameter scores changed from the fall of 1999 to the spring of 2000. Only the spring 2000 habitat assessments were used in this report to determine habitat condition.

Dissolved oxygen, conductivity, temperature, and pH were measured in situ using a Corning Check Mate Field Meter. The field chemical/physical measurements were taken directly upstream of the biological sampling site, prior to benthic sampling. The field chemical/physical parameters were generally measured at all sites with sufficient flow in each season, except for dissolved oxygen. Dissolved oxygen was not measured at all sites in the spring of 1999 due to meter malfunction.

Substrate size characterizations were measured using USEPA Environmental Monitoring and Assessment Program (EMAP) protocols (Lazorchak et al 1998, and Kaufmann et al 1999). This method was slightly modified from the original in that 100 meters were used for the study reach at all streams with an average wetted width of 2.5 meters or smaller. At some of the larger sampling sites, forty times the wetted width was sampled, up to a maximum of 500 meters. Starting at zero meters, eleven transects at equal intervals were measured over the sampling reach. These transects were defined by the wetted width. Five measurements were taken at evenly spaced intervals across each transect (left, left middle, middle, right middle, and right). Substrate particles in the transects were assigned to substrate classes. Five particles were randomly selected, measured and assigned a substrate size class in each of the 11 transects, for a total of 55 particle measurements. The 55 measurements and resulting size classes were used to estimate the proportion of bedrock, boulder, cobble, coarse gravel, fine gravel, and sand and fines present in the reach and the mean particle size in the reach. Bankfull height, thalweg depth, slope, and wetted width were also recorded for the reach. Thalweg depth and wetted width were recorded for each transect. Average bankfull height and overall slope were calculated for the reach.

The substrate size characterizations were measured twice during the study period at selected sites. Measurements were taken at all sites sampled for benthic macroinvertebrate in the fall of 1999. However, the low flow prevented sampling of several sites. Thus, the substrate measurements were repeated at all sites in the spring of 2000, to provide complete data for all sites. Only the spring 2000 substrate size measurements were used to characterize substrate conditions.

Land cover information for the subwatersheds upstream of the sampled sites was considered for use in this report. However, after extensive review of the land cover data set, ground-truthing, and input from our peer reviewers, we decided the information did not accurately represent the land cover in the subwatersheds at the time the biological and chemical data were collected. The percent land cover classified as Quarries/Mining appeared to underestimate the actual area surface mined because surface mining has continued since 1993 (the Landsat images were made in 1993). Furthermore, older surface mines were classified as grasses or forest cover if they were covered with vegetation when the 1993 Landsat images were made. Similarly, residential land cover did not seem to be properly characterized by the Landsat images. We believe this is due both to the age of the land cover, and the small size of the residential tracts in this region of southern West Virginia. Many of the residential units are single trailers in very narrow strips along the streams.

3.0 WATERSHED DESCRIPTIONS

Detailed descriptions of the sampling sites and a table of several attributes for the sampling sites are included in Appendix 1 (e.g. locational information, EIS class, stream order, watershed size).

3.1 Mud River Watershed

The headwaters of the Mud River rise in Boone County and flow in a northwesterly direction into Lincoln County. Most of the watershed lies in Lincoln County. The headwaters of the Mud River watershed do not lie in the primary mountaintop mining area as described by the West Virginia Geological and Economic Survey (figure 1). In this watershed, the area of concern is a strip of land approximately five miles wide that runs perpendicular to the watershed and straddles the Boone and Lincoln County line. The remaining downstream watershed is out of the area of concern.

From the headwaters to the northwestern boundary of the primary mountaintop mining area, the watershed lies in the Cumberland Mountains of the Central Appalachian Plateau (subecoregion 69d) (Woods et al 1999) (figure 2). Woods et al describe the physiography as being unglaciated, dissected hills and mountains with steep slopes and very narrow ridge tops. The geology is described as being Pennsylvania sandstone, siltstone, shale, and coal of the Pottsville Group and Allegheny Formation. The primary land use is forest with extensive coal mining, logging, and gas wells. Some livestock farms and scattered towns exist in the wider valleys. Most of the low-density residential land use is concentrated in the narrow valleys.

The remainder of the watershed lies in the Monongahela Transition Zone of the Western Allegheny Plateau (subecoregion 70b). The Monongahela Transition Zone is outside the primary area of mountaintop mining. However it is mined and there are fills associated with this mining. This area is unglaciated with more rounded hills, knobs, and ridges compared to the dissected hills and mountains with steep slopes and very narrow ridge tops found in the Central Appalachian Plateau (Woods et al 1999). Land slips do occur in the Monongahela Transition Zone. The geology is Permian and Pennsylvanian interbedded sandstone, shale, limestone and coal of the Monongahela Group and less typically the Waynesboro Formation. The primary land use is forest with some urban, suburban, and industrial activity in the valleys. There is also coal mining and general farming in this region.

3.2 Spruce Fork Watershed

The Spruce Fork watershed drains portions of Boone and Logan Counties. The stream flows in a northerly direction to the town of Madison where it joins Pond Fork to form the Little Coal River. About 85 to 90 percent of the watershed resides in the primary mountaintop mining region (figure 1). Only the northwest corner lies outside this region. The entire watershed lies within subecoregion 69d (Cumberland Mountains) (figure 2). The watershed has been the location of surface and underground mining activity for many years, and numerous subwatersheds have been disturbed.

3.3 Clear Fork Watershed

Clear Fork flows in a northwesterly direction to its confluence with Marsh Fork where they form the Big Coal River near Whitesville. The entire watershed lies within Raleigh County. All but a tiny part of the watershed is within the primary mountaintop mining area and is within subecoregion 69d (Cumberland Mountains) (figures 1 and 2). The coal mining industry has been active in this watershed for many years. Both surface and underground mining have occurred in the past and continue today. Two subwatersheds, Sycamore Creek and Toney Fork, were sampled as part of this survey.

3.4 Twentymile Creek Watershed

Twentymile Creek drains portions of four counties: Clay, Fayette, Kanawha, and Nicholas. It flows generally to the southwest where it joins the Gauley River at Belva, West Virginia. Except for a small area on the western edge of the watershed, it is within the primary mountaintop mining area, and it all lies within subecoregion 69d (Cumberland Mountains) (figures 1 and 2). The watershed upstream of Vaughn is uninhabited. Logging, mining, and gas wells are the primary activities upstream of Vaughn. There has been a limited amount of old mining in the watershed above Vaughn but the majority of the mining activity is more recent. Downstream of Vaughn there are numerous residences and some small communities.

3.5 Island Creek Watershed

Island Creek flows in a generally northerly direction to Logan where it enters the Guyandotte River. The entire watershed is confined to Logan County. All but the northern part of the watershed lies in the primary mountaintop mining area and the entire watershed is located in subecoregion 69d (Cumberland Mountains) (figures 1 and 2). Extensive underground mining has occurred in the watershed for many years. As these reserves have been depleted and economics have changed, surface mining has taken on a bigger role in the watershed.

4.0 DATA ANALYSIS METHODS

4.1 Multi-Metric Stream Condition Index

Several individual metrics and a multi-metric index were used to evaluate the benthic macroinvertebrate data. A multi-metric index known as the Stream Condition Index (SCI) was developed by Tetra Tech, Inc. using WVDEP benthic data for West Virginia wadeable streams (Gerritsen et al 2000). This index was developed to detect impact from a broad range of stressors, not solely for mining related impacts. The SCI was developed from a data set of 1268 benthic samples (including 107 reference samples) collected in riffle habitats from 1996 to 1998. The SCI was originally developed using data collected from 1996 to 1997 and was later validated using an independent dataset collected in 1998. The SCI was developed in accordance with EPA guidance (Barbour et al 1999).

Six metrics make up the SCI: Total Taxa, Ephemeroptera Plecoptera Trichoptera (EPT) Taxa, % EPT, % Chironomidae, % Two Dominant Taxa, and a family-level Hilsenhoff Biotic Index (HBI). We relied heavily on the multimetric SCI as an overall indicator of stream condition and to report stream condition classes of very good, good, fair, poor and very poor. The individual metric values that make up the SCI were also used to analyze differences between the classes.

The six metrics were aggregated into an index by calculating the 5th percentile (% Chironomidae, % Two Dominant Taxa, HBI) or 95th percentile (% EPT, Total Taxa, EPT Taxa) for all 720 sampling sites in the WVDEP 1996-1998 database. These values were considered the standard, "best" values. These values were then assigned a score of 100. Values of a metric between the minimum possible value (or in some cases the maximum possible value) and the standard best score were then scored proportionally from 0 ("worst") to 100 ("best"). By standardizing the metric values to a common 100-point scale, each of the metrics contributes to the combined index with equal weighting, and all of the metric scores represent increasingly "better" site conditions as scores increase toward 100. Once all metric values for sites were converted to scores on the 100-point scale, a single multi-metric index value was calculated by simply averaging the individual metric scores for the site.

Thresholds for the index were developed using the SCI scores of the 107 reference samples. Index scores that exceed the 25th percentile of the reference site scores (>78) are considered to be highly comparable to the WVDEP reference sites and in very good condition. Index scores that are greater than the 5th percentile(>70) up to the 25th percentile of the reference site scores (78) are considered to be comparable to the below-average WVDEP reference sites and in good condition. Scores equal to or less than the 5th percentile of the reference site scores (70) are considered to be increasingly different from the WVDEP reference condition and impaired. Scores greater than 46 and up to 70 indicate fair conditions, scores greater than 23 and up to 46 indicate poor conditions, and scores between 0 to 23 indicate very poor conditions (Gerritsen et al 2000).

Richness metrics have been shown to be positively correlated with abundance (Gerritsen et al

2000). The target minimum sample size for this study was 100 individuals. For this project, the WVDEP samples were rarefied from their original target count of 200 organisms to 100 individuals to recalculate the standard best values for total taxa richness and EPT taxa richness. We then rarified our data to 100 organisms as well in order to score our samples using the rarefied SCI best standard values. Rarefaction is a statistical procedure which lets you directly compare the number of taxa found in samples when the sampling effort differed. Rarefaction uses the data from the original sample to answer the questions "how many taxa would have been found in a smaller sample?". Rarefaction takes hypothetical subsamples of 100 organisms from the original sample, and calculates the richness metrics for each hypothetical subsample (Krebs 1998). Our rarefaction procedure took 100 hypothetical subsamples of 100 organisms from the original sample, and calculated an average taxa richness and EPT richness metric values for those 100 subsamples.

The scores for the WVDEP reference sites were recalculated using the rarefied SCI and the 5th and 25th percentiles were determined to establish the scoring ranges. The rarefied SCI is a slight modification to the original WV SCI. This modification was made to avoid a possible bias in the richness metrics by scoring samples with more organisms higher than samples with fewer organisms, possibly simply because there are more organisms (and hence more taxa) in one sample. These modifications did not make a difference in the final conclusions of this report.

4.2 Expectations for Individual Metric Values

General expectations for metric values in healthy streams were based on several years of assessment experience and the ranges of values found in the independent dataset of WVDEP reference sites used to develop the SCI.

The metric Total Taxa richness measures the number of families in the sample. Total Taxa richness generally decreases with increasing stream degradation. We generally expect healthy streams to have at least 20 taxa at the family level.

The metric EPT Taxa measures taxa richness in three insect orders known to be generally sensitive to disturbance (Ephemeroptera, Plecoptera, Trichoptera or mayflies, stoneflies and caddisflies, respectively). EPT Taxa generally decreases with degrading stream condition. Healthy streams in West Virginia commonly have 9 to 12 EPT taxa at the family level (Gerritsen et al 2000). This is a widely used index and is very sensitive to changes in water quality. One study found that the EPT index was sensitive to chemical-induced disturbances, but was relatively insensitive to natural disturbances, such as extreme discharges in small headwater streams (Wallace et al 1996). This same study found that the EPT index showed a "remarkable ability to track secondary production of invertebrates".

The metric % EPT is based on the proportion of individuals in the sample that belong to the EPT orders. We generally expect that in healthy streams, a high percentage of the total organisms present should belong to the EPT orders. It is common in healthy streams that at least 70 to 90% of the total organisms are in these sensitive orders.

The metric % Chironomidae is based on the proportion of individuals in the sample that belong to the family Chironomidae. This metric generally increases with degrading stream condition. Since Chironomidae are very small organisms, the mesh size of the collecting net can affect the number of midges collected. This study and the WVDEP monitoring program used nets with 595 micron mesh size. Studies using smaller mesh sizes may result in higher numbers and relative abundance of Chironomidae. Based on the WVDEP dataset, and our experience using the 595 micron mesh net, it is not uncommon in healthy streams that less than 20% of the organisms in the sample belong to the family Chironomidae.

The Hilsenhoff Biotic Index (HBI) weights each taxon in a sample by its proportion of individuals and the taxon's tolerance value. Tolerance values are assigned to each family on a scale of 0 to 10, with 0 identifying the least tolerant (most sensitive) organisms, and 10 identifying the most tolerant (least sensitive) organisms. The HBI metric can be thought of as an average organic pollution tolerance value for the sample, weighted by the abundance of organisms. This metric increases with degrading stream conditions, especially where organic enrichment is present. Since some of the organic-tolerant organisms are also tolerant to other stressors, the HBI is often used as a general indication of stress. It is not uncommon for healthy streams with good water quality to have family-level HBI values in the range of 3 to 4.

The metric % Two Dominant Taxa is based on the proportion of individuals in the sample that belong to the two most dominant taxa. In healthy streams, there are generally several families, with the individuals evenly distributed among the different families. As stream degradation occurs, more individuals are concentrated in fewer, more tolerant families, and this metric generally increases. It is not uncommon for healthy streams to have as few as 40-60% of the total individuals in a sample in the 2 dominant taxa.

In addition to the individual metrics that make up the SCI, we also used the metrics Mayfly Taxa and % Mayfly to evaluate the data. Preliminary analysis of the spring 1999 benthic assemblage data indicated that mayfly populations were impaired in the filled streams. These metrics have been widely tested and found useful in numerous studies and are suggested for use in the EPA Rapid Bioassessment Protocols and related guidance (Barbour et al 1999).

The metric Mayfly Taxa enumerates the number of families of mayflies. Mayflies are generally sensitive organisms, and in healthy streams, it is not uncommon to find at least 3 or 4 families of mayflies. The metric % Mayfly is based on the proportion of individuals in the sample that are mayflies. Since mayflies are generally sensitive organisms, this metric decreases with increasing degradation. It is not uncommon for healthy streams to have as many as 20-40% of the total individuals in the sample be mayflies. As streams are degraded, the sensitive mayflies may be replaced with less sensitive taxa. Both metrics (Mayfly Taxa and % Mayfly) have been used in other multimetric indices and have been found to discriminate between reference and impaired sites (Voshell and Smith 1997, Stribling et al 1998, Barbour et al 1999).

4.3 Grouped Sites Analysis

Sites were grouped over the entire region by the four classes: unmined (no mining activity or residences upstream of the sampled site), filled (valley fill or fills upstream of sampling site but no residences), filled/residential (valley fill or fills upstream of sampling site and residences), and mined (some type of past mining activity upstream of sampling site, but no valley fills and no residences). The unmined class was used as the control class. We analyzed each season separately to minimize the effects of seasonal variability.

We calculated the mean and standard deviation of the metric scores for each class in each season. We compared the means of the four classes in each season. We also calculated the percentage of total sites in each SCI condition class (very good, good, fair, poor, very poor) by season and over all five seasons. We used box and whisker plots to compare the interquartile ranges (25th percentile to 75th percentile) of the metric values of the classes to the unmined control class.

In the box and whisker plots, we also compared our data to the subset of seven WVDEP reference sites that are located in the MTM/VF region. Three of these sites are located in the Elk Watershed (Camp Creek, Ike Fork, and Johnson Branch). Three of the sites are located in the Gauley Watershed (Bearpen Fork, Ash Fork, and Neil Branch). One site is located in the Lower Guyandotte Watershed (Laurel Creek). Six of the seven WVDEP reference sites are different locations from our unmined sites and provide another, independent point of reference for comparison. Six of the these WVDEP reference sites were sampled in July of 1997 and 1998 and one of these sites was sampled in May 1998. Although the WVDEP reference sites are not strictly comparable to our sites in seasons outside of the summer, they are provided as an optional point of reference in the box and whisker plots.

The two sites that were classified as mined but also had residences in their watersheds were not used in the analysis of the classes because there were so few sites in that class (MT01 and MT69). The site in the sediment control structure (MT24) was also not included in the analysis of the classes since it is the only site of this type and does not represent a natural stream habitat.

Several of the unmined streams could not be sampled during the summer and fall of 1999 due to the drought. We relied on the complete data sets collected in the spring 1999, winter 2000, and spring 2000 seasons to characterize condition in the streams using the unmined class as the control class. Descriptive statistics and graphs for the summer and fall 1999 seasons are included in the report for completeness.

Box-and-whisker plots and vertical point plots were used to evaluate differences in the interquartile ranges of metric values among the four classes. The box and whisker plots display descriptive statistics (median, mean, 25th percentile, 75th percentile, 10th percentile, 90th percentile, and outliers) of a population of sites. The box displays the upper quartile (75th percentile) and the lower quartile (25th percentile). The whiskers display the 90th percentile and the 10th percentile. The solid line in the box is the median. The dotted line in the box is the mean. Box and whisker plots are displayed for only those classes with at least 4 data points. Vertical point plots display all of the data points as an overlay on the box plot. For those classes and seasons where fewer than 4 sites were sampled, only the vertical point plot is shown on the graph.

The degree of overlap of the metric ranges in the four classes (i.e., unmined, filled, filled/residential and mined) was used to visually determine the degree of difference between the populations. No overlap of the interquartile ranges of metric values for the populations indicates the greatest degree of difference between the classes. Some overlap of the interquartile ranges, but the medians of the populations are outside of the interquartile overlap, indicates the next greatest degree of difference between classes. Moderate overlap of the interquartile ranges, but at least one median outside the interquartile range overlap indicates some difference between the classes. Extensive overlap of interquartile ranges and both medians within the overlap indicates little or no difference between the classes (Barbour et al 1996).

5.0 BIOLOGICAL CONDITION OF STREAMS

To assess the overall ecological condition of streams in the primary region of mountaintop coal mining, we relied on direct measures of the benthic communities that inhabit the streams. Biological communities reflect overall ecological integrity (i.e. chemical, physical and biological integrity). Therefore, biosurvey results directly assess the status of a waterbody relative to the primary goal of the Clean Water Act. The aquatic insects and other benthic organisms integrate the effects of all stressors to which they are exposed including water quality, degradation of physical habitat, and flow, and thus provide a broad measure of their aggregate adverse effect. These organisms also integrate stressors over time since many of them live in the water for periods of a year or more. Therefore, they provide an ecological measure of fluctuating conditions, rather than a snapshot like grab water quality measurements. Finally, where criteria for specific ambient impairments do not exist (i.e. effects that degrade habitat), biological communities are often the only practical means of evaluating the condition of streams (Barbour et al 1999).

5.1 Benthic Data: Summary of Findings

The West Virginia Stream Condition Index scores are summarized in tables 1 and 2. The percentage of sites in each condition class (very good, good, fair, poor and very poor) are presented by season and then by stream class in table 1. This table allows a quick analysis of how the site classes compared to each other within a season. The percentage of sites in each condition class are presented by stream class and then by season in table 2. This table allows a quick analysis of how the conditions of each site class changed from season to season.

In the seasons with complete data sets (spring 1999, winter 2000, and spring 2000), the unmined sites generally scored in the good to very good range using the WVDEP Stream Condition Index. Over all five seasons, the unmined sites scored in the very good range 72% of the time and in the good range 19% of the time (table 2). It is important to note that although many of the unmined sites could not be sampled in the fall and summer of 1999 due to the severe drought and low flows, once they could be sampled effectively, these sites scored in the good to very good range.

In contrast to the unmined sites, the filled sites scored over the entire range of conditions. Over all five seasons, the filled sites scored in the very good range 14% of the time, in the good range 19% of the time, in the fair range 53% of the time, in the poor range 12% of the time, and in the very poor range only 1% of the time. We believe the range of biological conditions found in the filled sites can be explained by differences in water quality (see section 7.0 for a discussion of the associations between biological condition and conductivity).

The filled/residential class showed even more impairment. Over all five seasons, sites scored in the fair range 43% of the time, and in the poor range 57% of the time. None of the sites in this class ever scored in the good or very good range.

Table 1. Summary of Stream Conditions Based on the WV Stream Condition Index
Percentage of Sites in Each Condition Category by Season

Stream Class (n)	Very Good (>78-100)	Good (>70-78)	Fair (>46-70)	Poor (>23-46)	Very Poor (0-23)
Spring 1999					
Unmined (9)	67	33	0	0	0
Filled (15)	27	7	53	13	0
Filled/residential (6)	0	0	17	83	0
Mined (4)	75	0	0	25	0
Summer 1999*					
Unmined (2)	0	50	50	0	0
Filled (15)	0	0	100	0	0
Filled/residential (6)	0	0	67	33	0
Mined (2)	50	50	0	0	0
Fall 1999*					
Unmined (2)	0	50	0	50	0
Filled (14)	7	43	50	0	0
Filled/residential (6)	0	0	83	17	0
Mined (1)	100	0	0	0	0
Winter 2000					
Unmined (9)	78	11	11	0	0
Filled (14)	21	14	50	14	0
Filled/residential (6)	0	0	33	67	0
Mined (3)	100	0	0	0	0
Spring 2000					
Unmined (10)	100	0	0	0	0
Filled (15)	13	33	13	33	7
Filled/residential (6)	0	0	17	83	0
Mined (5)	60	20	0	20	0

* A number of streams lacked sufficient flow to sample during the severe drought. For more detail on the drought and its effect on sampling, see section 2.3 and Appendix 6.

Very few mined sites were sampled. Over all five seasons, these sites scored in the very good range 73% of the time, in the good range 13% of the time, and in the poor range 13% of the time. The samples that scored in the poor range were collected at the same site, MT78. We believe this site is naturally flow limited for most of the year, not only during periods of drought. The other mined sites have limited amounts of mining activity in their watersheds. Many of these sites were thought to be unmined prior to the first round of field sampling and ground-truthing.

Over all three seasons with complete data sets (spring 1999, winter 2000 and spring 2000), the same pattern was evident: unmined sites scored generally in the good to very good range; the filled class described a wide range of conditions and over half of the filled sites were impaired relative to the unmined class; and the filled/residential class scored in the fair to poor range and all filled/residential sites were impaired relative to the unmined class.

Our data illustrate the ability of the benthic assemblages in the unmined streams to withstand natural periods of drought. Other studies have also concluded that intermittent streams are clearly capable of supporting diverse and abundant invertebrate assemblages:

For example, in Western Oregon taxa richness of invertebrates (>125 species) in temporary forest streams exceeded that in a permanent headwater stream (100 species) (Dietrich and Anderson 2000). Dietrich and Anderson also found that only 8% of the species in the total collection were only found in the permanent headwater. 25% were restricted to the summer-dry streams and 67% were in both permanent and summer-dry streams. In other words, most of the aquatic life found in the temporary streams were also found in permanent streams, clearly indicating that the temporary streams support aquatic life similar to that found in permanent streams. These researchers concluded that the potential of summer-dry streams with respect to habitat function is still widely underestimated.

In northern Alabama, Feminella (1996) quantified the flow in six similar-sized streams and compared benthic macroinvertebrate communities in those same six upland streams of varying hydrologic permanence . Two of the streams were normally intermittent, three occasionally intermittent, and one rarely intermittent. Despite the differences in flow, the invertebrate assemblages differed only slightly. Presence-absence data revealed that 75% of the species were found in all six streams or showed no pattern with respect to flow permanence. Seven percent (7%) of the total species were found exclusively in the normally intermittent streams. In other words, the benthic assemblage can withstand periods of dryness, probably by burrowing into the wet subsurface zones or taking refuge in residual pools.

Many researchers have found that intermittent streams, springbrooks and seepage areas contain not only diverse invertebrate assemblages, but some unique aquatic species. Dieterich and Anderson (2000) found 202 aquatic and semi-aquatic invertebrate species, including at least 13 previously undescribed taxa. Morse et al (1997) have reported that many rare invertebrate species in the southeast are known from only one of a few locations with pea-sized gravel or in springbrooks and seepage areas. Kirchner (F. Kirchner pers. comm. 2000 and Kirchner and Kondratieff 2000) reports 60 species of stoneflies from eastern North America are found only in first and second order streams, including seeps and springs. 50% of these species have been described as new to science in last 25-30 years.

Williams (1996) reported that virtually all of the aquatic insect orders contain at least some species capable of living in temporary waters and that a wide variety of adaptations across a broad phylogenetic background has resulted in over two-thirds of these orders being well represented in temporary waters. This researcher goes on to say that “perhaps the concept of temporary waters constraining their faunas is based more on human perception than on fact”.

We have conducted field surveys to confirm the extent of perennial and intermittent stream reaches that would be buried by mountaintop mining valley fills proposed in specific permits. This field work indicated that the 1:24,000 USGS topographic maps underestimate both the perennial and intermittent stream resources (Green and Passmore 1999a, Green and Passmore, 1999b). These field surveys indicated that all of the sites that were classified as intermittent based on flow supported aquatic life very similar to the sites classified as perennial based on flow. These surveys and others indicate that intermittent flow alone is a poor indicator of the abundance and diversity of aquatic life supported by a stream.

Other field work done in support of the Mountaintop Mining/Valley Fill EIS assessed the potential limits of viable aquatic communities in small headwater streams in southern West Virginia (Kirchner et al 2000). This study found that a number of taxa that were found in the extreme headwaters have multi-year life cycles suggesting that sufficient water is present for long-lived taxa to complete their juvenile development prior to reaching the aerial adult stage. Although only contiguous flow areas were considered for this study, the field work took place in the winter and based on our field experience and that of the authors, it is probable these extreme headwaters are subject to annual drying.

Table 2. Summary of Stream Conditions Based on the WV Stream Condition Index
Percentage of Sites in Each Condition Category by Stream Class

Season (n)	**Very Good (>78-100)**	**Good (>70-78)**	**Fair (>46-70)**	**Poor (>23-46)**	**Very Poor (0-23)**
Unmined					
Spring 1999 (9)	67	33	0	0	0
Summer 1999 (2)	0	50	50	0	0
Fall 1999 (2)	0	50	0	50	0
Winter 2000 (9)	78	11	11	0	0
Spring 2000 (10)	100	0	0	0	0
Total for all seasons (32)	72	19	6	3	0

Table 2. Summary of Stream Conditions Based on the WV Stream Condition Index Percentage of Sites in Each Condition Category by Stream Class					
Season (n)	**Very Good (>78-100)**	**Good (>70-78)**	**Fair (>46-70)**	**Poor (>23-46)**	**Very Poor (0-23)**
Filled					
Spring 1999 (15)	27	7	53	13	0
Summer 1999 (15)	0	0	100	0	0
Fall 1999 (14)	7	43	50	0	0
Winter 2000 14)	21	14	50	14	0
Spring 2000 (15)	13	33	13	33	7
Total for all seasons (73)	14	19	53	12	1
Filled/residential					
Spring 1999 (6)	0	0	17	83	0
Summer 1999 (6)	0	0	67	33	0
Fall 1999 (6)	0	0	83	17	0
Winter 2000 (6)	0	0	33	67	0
Spring 2000 (6)	0	0	17	83	0
Total for all seasons (30)	0	0	43	57	0
Mined					
Spring 1999 (4)	75	0	0	25	0
Summer 1999 (2)	50	50	0	0	0
Fall 1999 (1)	100	0	0	0	0
Winter 2000 (3)	100	0	0	0	0
Spring 2000 (5)	60	20	0	20	0
Total for all seasons (15)	73	13	0	13	0

5.2 Spring 1999 Benthic Data

The spring 1999 data set included nine (9) unmined sites, fifteen (15) filled sites, six (6) filled/residential sites and four (4) mined sites. A summary of the spring 1999 benthic data is provided in table 3 and in figures 8 - 16 in Appendix 4.

The spring 1999 data indicate that all of the unmined sites met our expectations for healthy streams based on the broader West Virginia reference condition. All of these streams were in good or very good condition. The class of unmined sites includes primarily forested watersheds with few or no known stressors. The tight range of metric values and conditions in the unmined class supports the conclusion that characteristics of minimally impaired streams are fairly comparable over the MTM/VF region.

Table 3. Summary of Spring 1999 Benthic Data (mean and standard deviation)

Metric: mean (standard deviation)	**EIS Class**			
	Unmined (n=9)	**Filled (n=15)**	**Filled/residential (n=6)**	**Mined (n=4)**
WV SCI	82.0 (7.8)	61.9 (14.6)	42.2 (9.9)	72.4 (22.7)
Total Taxa	20.6 (4.2)	15.2 (3.9)	14.0 (2.6)	17.3 (7.3)
EPT Taxa	13.2 (3.2)	7.9 (3.6)	6.3 (2.0)	10.8 (5.0)
%EPT	67.2 (13.6)	50.5 (23.3)	18.5 (11.2)	52.4 (30.6)
HBI	3.8 (0.7)	4.6 (0.7)	6.0 (0.5)	4.7 (1.8)
% 2 Dominant	47.3 (9.1)	63.7 (11.3)	71.6 (8.2)	57.3 (23.6)
% Chironomidae	20.4 (14.0)	28.9 (17.3)	50.4 (16.1)	17.3 (14.0)
Mayfly Taxa	4.9 (0.8)	1.6 (1.3)	2.3 (2.0)	3.8 (1.9)
% Mayflies	37.4 (11.2)	10.3 (16.7)	3.5 (5.7)	21.3 (17.8)

Condition Categories for the WV SCI:
>78-100 Very Good - Highly comparable to WVDEP reference sites
>70-78 Good - Comparable to below-average WVDEP reference sites
>46-70 Fair
>23-46 Poor
0-23 Very Poor

Conditions in the filled sites ranged from poor to very good conditions. The majority of the filled sites were in fair condition (53%). However, over a third of the filled sites were in good or very good condition (34%). The filled sites range from a site that has only one, very small fill in the headwaters (MT52) to sites that have several fills in their headwaters.

Conditions in the filled/residential sites ranged from poor to fair. Eighty-three (83%) of these sites were in poor condition in the spring of 1999. Conditions in the mined sites were either poor (25%) or very good (75%). Most of the sites in this class have minimal mining in their watersheds. The site (MT78) that scored poor is probably naturally limited by flow even during normal flow periods. We believe this site only flows in response to precipitation events and snow melt.

The descriptive statistics and the box and whisker plots indicate that the class of unmined sites was different from the class of filled sites in the spring of 1999 (see table 3 and figures 8-16). For every individual metric and the SCI, the mean values of the metrics in the filled sites class indicate some impairment relative to the unmined sites. In the box and whisker plots, there was no overlap of the interquartile ranges (25th percentile to the 75th percentile) of the unmined and filled classes for the metrics Mayfly Taxa, % Mayflies, EPT Taxa, Total Taxa, and % Two Dominant Taxa. For the SCI, modified HBI, and %EPT, there was some overlap of the interquartile ranges, but the medians of both classes were outside of the interquartile overlap. There was substantial overlap of the ranges for the metric % Chironomidae.

The descriptive statistics and the box and whisker plots indicate that the class of unmined sites was different from the class of filled/residential sites in the spring of 1999. For every metric, the mean values and the range of values in the filled/residential sites indicate some impairment relative to the unmined sites. There was no overlap of the interquartile ranges (25th% - 75th%) of the unmined and filled/residential classes for any of the metrics.

Except for a single site (MT78), the data did not indicate that the mined class was impaired relative to the unmined class in the spring of 1999. As mentioned before, we believe the impaired stream is naturally limited by low flows, even during periods of non-drought conditions.

5.3 Summer 1999 Benthic Data

The summer 1999 data set included two (2) unmined sites, fifteen (15) filled sites, six (6) filled/residential sites and two (2) mined sites. A summary of the summer 1999 benthic data is provided in table 4 and in figures 17 - 25 in Appendix 4.

Ten of the sites could not be sampled in the summer of 1999. Riffle habitats at six of these sites were completely dry. At the other four sites, there was some flow, but not enough to collect a representative sample effectively. Seven of these sites are unmined sites (MT02 on Rushpatch Branch, MT03 on Lukey Fork, MT13 on Spring Branch, MT39 on White Oak Branch, MT50 and MT51 on Cabin Branch, and MT95 on Neil Branch). Two of these sites were mined sites (MT81 on Sycamore Creek, and MT78 on Raines Fork). One of the sites was a mined site with residences in the watershed (MT01 on the Mud River) and was not included in the class analysis. All of the filled sites had sufficient flow to be sampled in the summer of 1999.

Table 4. Summary of Summer 1999 Benthic Data (mean and standard deviation)				
Metric: mean (standard deviation)	**EIS Class**			
	Unmined (n=2)	**Filled (n=15)**	**Filled/residential (n=6)**	**Mined (n=2)**
WV SCI	72.9 (8.0)	60.3 (6.2)	50.0 (8.2)	75.6 (7.3)
Total Taxa	16.5 (0.7)	13.5 (2.5)	13.5 (1.9)	18.5 (0.7)
EPT Taxa	9.0 (0.0)	4.7 (1.6)	4.7 (1.2)	8.5 (0.7)
%EPT	47.0 (1.7)	53.6 (18.1)	30.7 (11.5)	64.1 (1.7)
HBI	4.6 (0.4)	5.0 (0.5)	5.5 (0.5)	4.3 (0.5)
% 2 Dominant	52.8 (21.2)	66.3 (13.3)	67.7 (9.0)	52.3 (14.3)
% Chironomidae	7.1 (1.8)	14.6 (11.0)	31.1 (15.0)	9.6 (6.4)
Mayfly Taxa	3.0 (0.0)	0.5 (0.6)	1.7 (1.5)	1.5 (2.1)
% Mayflies	11.8 (11.3)	0.5 (0.7)	1.8 (2.1)	10.5 (14.9)
Condition Categories for the WV SCI: >78-100 Very Good - Highly comparable to WVDEP reference sites >70-78 Good - Comparable to below-average WVDEP reference sites >46-70 Fair >23-46 Poor 0-23 Very Poor				

Since the summer 1999 data set is incomplete, only cursory comparisons could be made between the unmined control class and the other classes. The summer 1999 data indicate that one of the unmined sites was in good condition and one was in fair condition. All of the filled sites scored in the fair range in the summer of 1999. Conditions in the filled/residential sites ranged from poor to fair. Sixty-seven percent (67%) of the filled/residential sites were in fair condition in the summer of 1999. Conditions in the two mined sites were good and very good. The site that scored in the poor range in the spring of 1999 was completely dry and could not be sampled in the summer of 1999 (site MT78).

5.4 Fall 1999 Benthic Data

The fall 1999 data set included two (2) unmined sites, fourteen (14) filled sites, six (6) filled/residential sites and one (1) mined sites. A summary of the fall 1999 benthic data is provided in table 5 and in figures 26 - 34 in Appendix 4.

Eleven of the sites could not be sampled in the fall of 1999. The riffle habitat at one of these sites was completely dry. At the other ten sites, there was some flow, but not enough to collect a representative sample effectively. Seven of these sites were unmined sites (MT02 on Rushpatch Branch, MT03 on Lukey Fork, MT13 on Spring Branch, MT39 on White Oak Branch, MT42 on Oldhouse Branch, and MT50 and MT51 on Cabin Branch). Three of the these sites were mined sites (MT79 on Davis Fork, MT81 on Sycamore Creek, and MT78 on Raines Fork). One of the sites was a filled site (MT34B on the Left Fork of Beech Creek).

Since the fall 1999 data set is incomplete, only cursory comparisons could be made between the unmined control class and the other classes. The fall 1999 data indicate that one of the unmined sites was in good condition and one was in poor condition. We believe the unmined site in poor condition (MT95 on Neil Branch) was just recently flowing at the time of sampling. This site had been dry in the summer of 1999 and could not be sampled then. This site scored in the very good range in later sampling periods (winter 2000 and spring 2000). We do not believe the score in the fall of 1999 was representative of the conditions at this site based on the other three seasons (spring 1999, winter 2000 and spring 2000) of data.

Half of the filled sites scored in the fair range in the fall of 1999. The other half of the filled sites scored in the very good (7%) and good range (43%). Conditions in the filled/residential sites ranged from poor to fair. Eighty-three percent (83%) of these sites were in fair condition in the fall of 1999. The one mined site that could be sampled scored very good in the fall of 1999.

Table 5. Summary of Fall 1999 Benthic Data (mean and standard deviation)

Metric: mean (standard deviation)	**EIS Class**			
	Unmined (n=2)	**Filled (n=14)**	**Filled/residential (n=6)**	**Mined (n=1)**
WV SCI	56.9 (28.6)	68.8 (6.5)	56.7 (12.1)	88.7
Total Taxa	11.0 (9.9)	13.5 (3.0)	14.8 (3.0)	20.0

Table 5. Summary of Fall 1999 Benthic Data (mean and standard deviation)				
Metric: mean (standard deviation)	**EIS Class**			
	Unmined (n=2)	**Filled (n=14)**	**Filled/residential (n=6)**	**Mined (n=1)**
EPT Taxa	5.5 (5.0)	6.8 (2.3)	6.5 (2.5)	11.0
%EPT	45.0 (38.0)	72.2 (17.6)	45.0 (23.6)	83.0
HBI	4.9 (2.5)	3.3 (1.1)	4.7 (1.3)	2.9
% 2 Dominant	72.9 (25.5)	64.7 (11.3)	64.3 (15.0)	53.6
% Chironomidae	5.4 (7.6)	13.0 (10.4)	30.4 (20.5)	3.1
Mayfly Taxa	2.0 (2.8)	0.9 (0.9)	2.0 (1.3)	4.0
% Mayflies	1.1 (1.6)	0.8 (1.2)	1.3 (1.6)	7.1
Condition Categories for the WV SCI: >78-100 Very Good - Highly comparable to WVDEP reference sites >70-78 Good - Comparable to below-average WVDEP reference sites >46-70 Fair >23-46 Poor 0-23 Very Poor				

5.5 Winter 2000 Benthic Data

By the winter 2000 sampling period, most of the streams could be sampled, except for one mined site (MT78) which was completely dry and one filled site (MT34B) which was too low to sample. The winter 2000 data set included nine (9) unmined sites, fourteen (14) filled sites, six (6) filled/residential sites and three (3) mined sites. A summary of the winter 2000 benthic data is provided in table 6 and in figures 35 - 43 in Appendix 4.

The winter 2000 data indicate that most of the unmined sites met our expectations for healthy streams based on the broader West Virginia reference condition. Most of these streams (89%) were in good or very good condition. One site scored in the high fair range (MT39 had an SCI score of 67.8).

Conditions in the filled sites ranged from poor to very good conditions. Half of the filled sites were in fair condition (50%). However, over a third of the filled sites were in good or very good condition (35%).

Table 6. Summary of Winter 2000 Benthic Data (mean and standard deviation)

Metric: mean (standard deviation)	EIS Class			
	Unmined (n=9)	**Filled (n=14)**	**Filled/residential (n=6)**	**Mined (n=3)**
WV SCI	86.3 (9.6)	62.6 (17.9)	35.2 (11.0)	85.5 (7.5)
Total Taxa	19.0 (4.0)	16.2 (3.7)	13.3 (3.5)	21.3 (1.5)
EPT Taxa	12.1 (2.8)	9.2 (3.8)	6.3 (2.2)	14.3 (2.1)
%EPT	75.0 (12.8)	50.3 (23.7)	17.2 (13.6)	70.9 (4.9)
HBI	3.2 (0.7)	4.6 (1.1)	6.1 (0.7)	3.6 (0.4)
% 2 Dominant	45.9 (18.2)	63.2 (15.4)	81.2 (11.3)	41.8 (12.9)
% Chironomidae	13.4 (10.1)	37.1 (17.0)	66.1 (13.7)	22.5 (11.4)
Mayfly Taxa	4.1 (0.6)	1.9 (1.6)	1.0 (1.3)	4.0 (0.0)
% Mayflies	26.3 (11.6)	6.9 (11.2)	0.5 (0.8)	27.1 (12.5)

Condition Categories for the WV SCI:
>78-100 Very Good - Highly comparable to WVDEP reference sites
>70-78 Good - Comparable to below-average WVDEP reference sites
>46-70 Fair
>23-46 Poor
0-23 Very Poor

Conditions in the filled/residential sites ranged from poor to fair. Over two-thirds of these sites (67%) were in poor condition in the winter of 2000.

All of the mined sites were in very good condition in the winter of 2000. Most of the sites in this class have minimal mining in their watersheds. The mined site that scored poor in the spring of 1999 (MT78) was still dry in the winter of 2000.

The descriptive statistics and the box and whisker plots indicate that the class of unmined sites was different from the class of filled sites in the winter of 2000 (see table 6 and figures 35 - 43). For every individual metric and the SCI, the mean value of the metrics in the filled sites class indicate some impairment relative to the unmined sites. In the box and whisker plots, there was no overlap of the interquartile ranges (25th percentile to the 75th percentile) of the unmined and filled classes for the metrics SCI, HBI, % Chironomidae, Mayfly Taxa, and % Mayflies. For the metrics %EPT, and % Two Dominant, there was some overlap of the interquartile ranges, but the medians of both classes were outside of the interquartile overlap. There was substantial overlap of the ranges for the metrics Total Taxa and EPT Taxa.

The descriptive statistics and the box and whisker plots indicate that the class of unmined sites was different from the class of filled/residential sites in the winter of 2000. For every metric, the mean values and the range of values in the filled/residential sites indicate some impairment relative to the unmined sites. There was no overlap of the interquartile ranges (25th% - 75th%) of the unmined and filled/residential classes for any of the metrics.

The winter 2000 data did not indicate that the mined class was impaired relative to the unmined class.

We also reviewed an independent benthic data set collected by Potesta and Associates for Arch Coal in the winter 2000 season (Potesta and Associates, Inc. 2000). Potesta and Associates also collected samples during the summer and fall 1999 seasons, but like ours, these data sets were incomplete (many sites could not be sampled due to the drought) and were of limited utility for comparing the other classes to the unmined class of streams. Potesta and Associates sampled the benthic assemblage using a Surber sampler. Six samples were collected at each site in the Mud River, Spruce Fork and Island Creek watersheds at the same time that our winter 2000 samples were collected. This independent data set indicates similar patterns in condition and generally supports our conclusions. Our analysis of the winter 2000 data set provided by Potesta and Associates indicated that the sites in the filled and filled/residential classes were impaired relative to the unmined sites (Green and Passmore 2000). The filled/residential class was the most impaired class.

5.6 Spring 2000 Benthic Data

The spring 2000 data set included ten (10) unmined sites, fifteen (15) filled sites, six (6) filled/residential sites and five (5) mined sites. Two sites were added in the spring of 2000. Site MT107 was established on the Left Fork of Cow Creek in the Island Creek Watershed and was classified as unmined. Site MT106 was established on an unnamed tributary to Sugartree Branch in the Mud River Watershed and was classified as mined. A summary of the spring 2000 benthic data is provided in table 7 and in figures 44 - 52 in Appendix 4.

The spring 2000 data indicate that all of the unmined sites met our expectations for healthy streams based on the broader West Virginia reference condition. All of these streams were in very good condition in the spring of 2000.

Table 7. Summary of Spring 2000 Benthic Data (mean and standard deviation)				
Metric: mean (standard deviation)	**EIS Class**			
	Unmined (n=10)	**Filled (n=15)**	**Filled/residential (n=6)**	**Mined (n=5)**
WV SCI	86.3 (4.6)	57.2 (22.6)	40.6 (5.4)	72.4 (18.6)
Total Taxa	17.9 (3.4)	13.5 (3.7)	12.7 (1.9)	16.2 (4.4)
EPT Taxa	11.6 (2.1)	7.7 (3.3)	7.3 (1.5)	10.8 (2.8)
%EPT	71.8 (10.2)	44.6 (30.8)	19.7 (7.9)	54.3 (17.4)
HBI	3.7 (0.5)	4.8 (1.2)	6.3 (0.5)	4.6 (0.9)
% 2 Dominant	42.4 (8.3)	68.1 (19.3)	77.9 (6.7)	56.5 (18.6)
% Chironomidae	14.1 (7.5)	34.0 (23.4)	60.6 (14.6)	36.1 (21.6)
Mayfly Taxa	4.5 (1.0)	1.5 (1.3)	2.2 (1.3)	3.6 (0.9)
% Mayflies	34.7 (9.7)	11.9 (13.4)	6.7 (5.6)	19.4 (12.8)
Condition Categories for the WV SCI: >78-100 Very Good - Highly comparable to WVDEP reference sites >70-78 Good - Comparable to below-average WVDEP reference sites >46-70 Fair >23-46 Poor 0-23 Very Poor				

Conditions in the filled sites ranged from very poor to very good conditions. The slim majority of the filled sites were in fair to very poor condition (53%). However, a large percentage of the filled sites were in good or very good condition (46%).

Conditions in the filled/residential sites ranged from poor to fair. Eighty-three (83%) of these sites were in poor condition in the spring of 2000.

Conditions in the mined sites were either poor (20%) or good or very good (80%). Most of the sites in this class have minimal mining in their watersheds. The site that scored poor was the site that had been dry since it was first sampled in the spring of 1999. We believe this site may only flow for a short period in the wet spring season.

The descriptive statistics and the box and whisker plots indicate that the class of unmined sites was different from the class of filled sites in the spring of 2000 (see table 7 and figures 44 - 52). For every individual metric and the SCI, the mean values of the metric in the filled sites class indicate some impairment relative to the unmined sites. In the box and whisker plots, there was no overlap of the interquartile ranges (25th percentile to the 75th percentile) of the unmined and filled classes for the metrics SCI, EPT Taxa, % Two Dominant, Mayfly Taxa and % Mayflies. For Total Taxa, HBI, and % Chironomidae, there was some overlap of the interquartile ranges, but the medians of both classes were outside of the interquartile overlap. There was more substantial overlap of the ranges for the metric %EPT.

The descriptive statistics and the box and whisker plots indicate that the class of unmined sites was different from the class of filled/residential sites in the spring of 2000. For every metric, the mean values and the range of values in the filled/residential sites indicate some impairment relative to the unmined sites. There was no overlap of the interquartile ranges (25th% - 75th%) of the unmined and filled/residential classes for any of the metrics.

Except for a single site (MT78), the data did not indicate that the mined class was impaired relative to the unmined class in the winter of 2000. As mentioned before, we believe the impaired stream is naturally limited by low flows, even during periods of non-drought conditions. This stream did not have any flowing water in it during the summer 1999, fall 1999, or winter 2000 sampling periods.

6.0 PHYSICAL/CHEMICAL CONDITION OF STREAMS

In the previous section, the ecological condition of the streams and stream classes was described using the benthic assemblage as a direct indicator of stream condition. This section describes the characteristics of potential stressors in these streams based on direct measurements of water quality, physical habitat, and substrate size and composition. We considered using land cover as a way to characterize potential stressors, but after extensive review of the readily available Landsat land cover data, we determined that these data were too dated and inaccurate to provide a current description of potential stressors.

6.1 Field Chemical/Physical Data : Summary of Findings

We measured conductivity, pH, temperature and dissolved oxygen, in the field, at the time of sampling. Sites were grouped over the entire region by the four classes (unmined, filled, filled/residential, and mined) and by season. Our data provided only limited information on water quality as only a single reading was taken during each field visit and some of the water quality parameters can be quite variable over the course of a day and over the seasons.

Conductivity is often used to estimate the total dissolved solids in water. The quantity of dissolved material in water depends mainly on the solubility of rocks and soils the water contacts. Most activities, including mining, logging, development, roads, etc., increase the total dissolved solids in a watershed. Mining disturbance can produce high sulfate values and extremely high conductivity. There is no aquatic life criterion for total dissolved solids or conductivity. In general, the filled and filled/residential classes had substantially higher conductivity than the unmined class (Tables 8 and 9 and figures 53, 56, 60, 64, and 68). This was the only obvious pattern in field chemical/physical parameters that held up over all five seasons. It should be noted that conductivity in the filled sites was generally comparable to or higher than conductivity in the filled/residential sites within a watershed. These data suggest that the probable cause of the increase in total dissolved solids at the filled/residential sites (compared to the unmined sites) was the mining activity, rather than the residences.

A range of pH from 6.0 to 9.0 is considered protective for most organisms in West Virginia's water quality standards. Changes in the water's pH can also affect aquatic life indirectly by changing other aspects of water quality. For instance, some metals are more mobile at lower pH levels. The toxicity of ammonia to fish also varies within a small range of pH values. Over the course of this study, pH measurements were always within the bounds of the aquatic life criteria (see figures 54, 57, 61, 65, and 69). Acidity did not appear to be limiting the aquatic life in these streams.

Aquatic organisms need dissolved oxygen to live. For warm water fisheries, a minimum of 5 mg/l dissolved oxygen at all times is required by West Virginia water quality standards. Over the course of this study, dissolved oxygen measurements were always greater than this minimum criterion (see figures 59, 63, 67, and 71). The data did not indicate any substantial differences between the classes.

Table 8. Summary of Water Quality Based on Field Chemical/Physical Data Mean by Season and Stream Class				
Stream Class (n)	**Conductivity (uS/cm)**	**pH (su)**	**Temperature (C)**	**Dissolved Oxygen (mg/l)**
Spring 1999				
Unmined (9)	64	7.5	13.5	*
Filled (15)	946	7.9	13.1	*
Filled/residential (6)	652	8.3	14.6	*
Mined (4)	172	8.4	11.8	*
Summer 1999				
Unmined (2)	140	7.3	23.4	6.5
Filled (15)	1232	7.7	21.0	7.5
Filled/residential (6)	1124	8.3	22.2	8.5
Mined (3)	385	7.1	19.5	8.7
Fall 1999				
Unmined (2)	91	7.5	8.8	11.5
Filled (14)	958	7.4	8.7	10.3
Filled/residential (6)	984	7.5	11.7	9.8
Mined (1)	260	6.7	6.3	10.4
Winter 2000				
Unmined (9)	73	7.7	1.6	13.3
Filled (14)	836	7.8	2.9	13.0
Filled/residential (6)	844	7.8	1.6	14.0
Mined (3)	254	7.3	2.2	12.7
Spring 2000				
Unmined (10)	58	7.1	12.1	9.5
Filled (15)	643	7.1	12.1	9.9
Filled/residential (6)	538	7.1	15.1	9.1
Mined (5)	192	6.9	12.6	9.9

* Dissolved oxygen was not measured at most sites in the spring of 1999.

Water temperature can determine which species may be present in a system. Temperature also affects feeding, reproduction, and the metabolism of aquatic animals. A week or two of high temperatures at critical times during the year may make a stream unsuitable for sensitive aquatic organisms or life stages. The West Virginia water quality standards indicate that temperature rise shall be limited to no more than 5 F or 2.7 C degrees above "natural" temperature, and should not exceed 87 F (31 C) at any time during the months of May through November and should not exceed 73 F (24 C) at any time during the months of December and April. Over the course of this study, none of the temperatures measured exceeded these seasonal maximums (see figures 55, 58, 62, 66, and 70). Temperature means were also fairly comparable within the four classes, and did not indicate any widespread rise above "natural" in any of the classes using the unmined class as the control class.

Table 9. Summary of Water Quality Based on Field Chemical/Physical Data Mean By Stream Class and Season

Season (n)	Conductivity (uS/cm)	pH (su)	Temperature (C)	Dissolved Oxygen (mg/l)
Unmined				
Spring 1999 (9)	64	7.5	13.5	*
Summer 1999 (2)	140	7.3	23.4	6.5
Fall 1999 (2)	91	7.5	8.8	11.5
Winter 2000 (9)	73	7.7	1.6	13.3
Spring 2000 (10)	58	7.1	12.1	9.5
Filled				
Spring 1999 (15)	946	7.9	13.1	*
Summer 1999 (15)	1232	7.7	21.0	7.5
Fall 1999 (14)	958	7.4	8.7	10.3
Winter 2000 14)	836	7.8	2.9	13.0
Spring 2000 (15)	643	7.1	12.1	9.9
Filled/residential				
Spring 1999 (6)	652	8.3	14.6	*
Summer 1999 (6)	1124	8.3	22.2	8.5
Fall 1999 (6)	984	7.5	11.7	9.8
Winter 2000 (6)	844	7.8	1.6	14.0
Spring 2000 (6)	538	7.1	15.1	9.1
Mined				

Table 9. Summary of Water Quality Based on Field Chemical/Physical Data Mean By Stream Class and Season				
Season (n)	**Conductivity (uS/cm)**	**pH (su)**	**Temperature (C)**	**Dissolved Oxygen (mg/l)**
Spring 1999 (4)	172	8.4	11.8	*
Summer 1999 (2)	385	7.1	19.5	8.7
Fall 1999 (1)	260	6.7	6.3	10.4
Winter 2000 (3)	254	7.3	2.2	12.7
Spring 2000 (5)	192	6.9	12.6	9.9
* Dissolved oxygen was not measured at most sites in the spring of 1999.				

Dissolved oxygen, pH and temperature can all vary during the day and through the seasons. The grab samples for these parameters may not be representative of water quality at these sites. Grab temperature measurements can be problematic since temperature clearly fluctuates during the day and seasonally in streams. Dissolved oxygen and pH levels can also vary over the course of a day due to changes in temperature, and changes in the photosynthesis daily cycle. Dissolved oxygen minimums occur in the very early morning hours, when community respiration is at its peak and the maximums occur during the afternoon when photosynthesis activity consumes carbon dioxide and produces oxygen. Therefore, grab dissolved oxygen measures taken during the day may not be representative of the critical minimum dissolved oxygen levels in a stream. Inorganic carbon in the form of carbon dioxide (a weak acid) is consumed during the day, so pH values can become elevated during the day and depressed at night. So, like grab temperature measurements, these grab dissolved oxygen and pH measurements should be treated with caution.

The seven WVDEP reference sites are provided on the box and whisker plots as an additional point of reference for the summer 1999 index period. These sites are not included on the box and whisker plots for other seasons because of the strong seasonal patterns in temperature and dissolved oxygen.

6.1.1 Spring 1999 Field Chemical/Physical Data

Conductivity, temperature and pH were measured at all of the sites, at the time of sampling, in the spring of 1999 (table 10). Conductivity means and interquartile ranges were much higher in the filled and filled/residential class than the unmined class (figure 53). Conductivity was consistently low in the unmined class. As a class, the filled sites had the highest mean conductivity.

The mean pH values and interquartile ranges were higher in the filled, filled/residential, and mined classes compared to the unmined class in the spring of 1999 (figure 54). The water quality standard for pH is 6.0 to 9.0. There were no pH values measured that could be considered to be harmful to aquatic life in the spring of 1999. Acidity did not seem to be a problem in the sites we sampled.

The means and interquartile ranges of temperature were quite similar for the unmined, filled and filled/residential classes (figure 55). The mean temperature was slightly, although not substantially, higher in the filled/residential class in the spring 1999 data set.

Table 10. Summary of Spring 1999 Field Chemical/Physical Data (mean and standard deviation)

Metric: mean (standard dev.)	**EIS Class**			
	Unmined (n=9)	**Filled (n=15)**	**Filled/residential (n=6)**	**Mined (n=4)**
Conductivity (uS/cm)	63.7 (19.1)	945.5 (614.0)	651.8 (236.5)	172.0 (90.4)
pH (su)	7.5 (0.7)	7.9 (0.6)	8.3 (0.3)	8.4 (0.3)
Temperature (C)	13.5 (2.0)	13.1 (1.4)	14.6 (2.9)	11.8 (5.1)
Dissolved Oxygen (mg/l)*				
Dissolved Oxygen was not measured in the spring of 1999 at most sites.				

6.1.2 Summer 1999 Field Chemical/Physical Data

Conductivity, temperature, pH and dissolved oxygen were measured at all of the sites, at the time of sampling, in the summer of 1999. Only two unmined sites could be sampled in the summer of 1999, so only cursory comparisons can be made between the classes. Conductivity means were substantially higher in the filled and filled/residential classes compared to the unmined class (table 11 and figure 56). Conductivity was consistently low in the unmined class. The filled sites had a slightly higher mean conductivity than the filled/residential sites. The highest mean conductivities of the study period occurred during the summer 1999 sampling period.

The mean pH measurements were higher in the filled and filled/residential classes compared to the unmined class in the summer of 1999. As in the spring, there were no pH values measured that could be considered to be harmful to aquatic life in the summer of 1999 (figure 57).

The ranges of temperature appeared to be similar for the unmined, filled, filled/residential, and mined classes in the summer of 1999 (figure 58).

Dissolved oxygen means were higher in the filled, filled/residential and mined sites than in the unmined sites in the summer of 1999. The dissolved oxygen measurements taken in the summer of 1999 were all above the minimum criterion of 5 mg/l (figure 59).

Table 11. Summary of Summer 1999 Field Chemical/Physical Data (mean and standard deviation)				
Metric: mean (standard dev.)	**EIS Class**			
	Unmined (n=2)	**Filled (n=15)**	**Filled/residential (n=6)**	**Mined (n=3)**
Conductivity (uS/cm)	139.5 (54.4)	1231.7 (643.4)	1123.8 (282.3)	385.3 (201.6)
pH (su)	7.3 (0.3)	7.7 (0.4)	8.3 (0.3)	7.1 (0.3)
Temperature (C)	23.4 (0.9)	21.0 (3.0)	22.2 (4.4)	19.5 (2.1)
Dissolved Oxygen (mg/l)	6.5 (1.2)	7.5 (1.0)	8.5 (1.0)	8.7 (1.3)

6.1.3 Fall 1999 Field Chemical/Physical Data

Conductivity, temperature, pH and dissolved oxygen were measured at most of the sites, at the time of sampling, in the fall of 1999 (table 12). A pH value could not be recorded at one of the filled/residential sites due to meter malfunction. Again, only two unmined sites could be sampled in the fall of 1999, so only cursory comparisons can be made between the classes. Conductivity means were again higher in the filled and filled/residential classes compared to the unmined class (figure 60). Conductivity was consistently low in the unmined class. The filled/residential sites had a slightly higher mean conductivity than the filled sites.

The mean pH measurements between the filled and filled/residential classes were comparable to the unmined class in the summer of 1999. As in the spring and summer, there were no pH values measured that could be considered to be harmful to aquatic life in the fall of 1999 (figure 61).

The ranges of temperature appeared to be similar for the unmined and filled classes (figure 62).

Dissolved oxygen means were lower in the filled, filled/residential and mined classes than in the unmined class in the fall of 1999. The dissolved oxygen measurements taken in the fall of 1999 were all above the minimum criterion of 5 mg/l (figure 63).

Table 12. Summary of Fall 1999 Field Chemical/Physical Data (mean and standard deviation)				
Metric: mean (standard dev.)	**EIS Class**			
	Unmined (n=2)	**Filled (n=14)**	**Filled/residential (n=6)**	**Mined (n=1)**
Conductivity (uS/cm)	91.1 (59.3)	958.3 (430.2)	984.3 (220.7)	260.0
pH (su)	7.5 (0.2)	7.4 (0.4)	7.5 (0.4)	6.7
Temperature (C)	8.8 (0.4)	8.7 (2.6)	11.7 (3.3)	6.3
Dissolved Oxygen (mg/l)	11.5 (0.3)	10.3 (1.2)	9.8 (0.6)	10.4

6.1.4 Winter 2000 Field Chemical/Physical Data

Conductivity, temperature, pH and dissolved oxygen were measured at most of the sites, at the time of sampling, in the winter of 2000. A pH value could not be recorded at one of the filled/residential sites due to meter malfunction. A dissolved oxygen value could not be recorded at one of the filled sites due to meter malfunction. Conductivity means were again substantially higher in the filled and filled/residential classes compared to the unmined class (table 13 and figure 64). Conductivity was consistently low in the unmined class. The filled/residential sites had a slightly higher mean conductivity than the filled sites.

The mean pH measurements between the filled and filled/residential classes were comparable to the unmined class in the winter of 2000. As in earlier seasons, there were no pH values measured that could be considered to be harmful to aquatic life in the winter of 2000 (figure 65).

The ranges of temperature were similar for the unmined, filled, filled/residential and mined classes (figure 66).

Dissolved oxygen means were comparable in the unmined, filled, filled/residential and mined sites in the winter of 2000. The dissolved oxygen measurements taken in the winter of 2000 were all well above the minimum criterion of 5 mg/l, due to the colder temperatures of the water (figure 67).

Table 13. Summary of Winter 2000 Field Chemical/Physical Data (mean and standard deviation)				
Metric: mean (standard dev.)	**EIS Class**			
	Unmined (n=9)	**Filled (n=14)**	**Filled/residential (n=6)**	**Mined (n=3)**
Conductivity (uS/cm)	72.8 (28.8)	836.2 (424.7)	844.0 (172.6)	254.3 (171.1)
pH (su)	7.7 (0.9)	7.8 (0.4)	7.8 (0.6)	7.3 (0.8)
Temperature (C)	1.6 (1.5)	2.9 (1.6)	1.6 (0.9)	2.2 (1.9)
Dissolved Oxygen (mg/l)	13.3 (0.8)	13.0 (0.9)	14.0 (1.5)	12.7 (1.6)

6.1.5 Spring 2000 Field Chemical/Physical Data

Conductivity, temperature, pH and dissolved oxygen were measured at all of the sites, at the time of sampling, in the spring of 2000.

Conductivity means were again substantially higher in the filled and filled/residential classes than in the unmined class (table 14 and figure 68). Conductivity was consistently low in the unmined class. The filled sites had a higher mean conductivity than the filled/residential sites.

The mean pH measurements between the filled and filled/residential classes were comparable to the unmined class in the spring of 2000. As in earlier seasons, there were no pH values measured that could be considered to be harmful to aquatic life in the spring of 2000 (figure 69).

The ranges of temperature were similar for the unmined, filled and mined classes in the spring of 2000 (figure 70).

Dissolved oxygen means were fairly comparable in the unmined, filled, filled/residential and mined sites in the winter of 2000. The dissolved oxygen measurements taken in the spring of 2000 were all above the minimum criterion of 5 mg/l (figure 71).

Table 14. Summary of Spring 2000 Field Chemical/Physical Data (mean and standard deviation)				
Metric: mean (standard dev.)	**EIS Class**			
	Unmined (n=10	**Filled (n=15)**	**Filled/residential (n=6)**	**Mined (n=5)**
Conductivity (uS/cm)	58.4 (27.8)	642.7 (381.8)	538.3 (249.0)	191.6 (155.1)
pH (su)	7.1 (0.7)	7.1 (0.8)	7.1 (0.6)	6.9 (1.0)
Temperature (C)	12.1 (1.8)	12.1 (2.1)	15.1 (2.6)	12.6 (1.9)
Dissolved Oxygen (mg/l)	9.5 (0.9)	9.9 (0.9)	9.1 (0.3)	9.9 (0.7)

6.2 Rapid Bioassessment Protocol Habitat Evaluations

Good physical habitat is important for maintaining stream condition. Instream and riparian habitat influence the structure and function of the aquatic community of a stream. For example, excessive sediment deposition can reduce habitat space and its availability. Parameters evaluated in the sampling reach include epifaunal substrate/available cover; embeddedness; velocity/depth regimes; sediment deposition; channel flow status; channel alteration; frequency of riffles; bank stability; bank vegetative protection; and riparian vegetation zone width. Only the spring 2000 habitat assessments were used to determine habitat condition.

In general, the physical habitat data do not indicate substantial differences between the unmined classes and the other classes. Some individual stations did have marginally degraded habitat, including excess sediment deposition. Three sites in the filled class (MT18, MT34B, and MT32) and two sites in the filled/residential class (MT23 and MT55) had degraded habitat scores in the spring of 2000.

In the Rapid Bioassessment Protocol (RBP) the individual habitat parameters are classified into four general condition classes based on a 20 point scoring system. Optimal habitat (meeting natural expectations) is scored from 16 to 20, suboptimal habitat (still has adequate habitat for maintenance of populations) is scored from 11 to 15, marginal habitat (moderate level of degradation/ frequent intervals of problems within the reach) is scored from 6 to 10, and poor habitat (where the characteristic of the parameter is substantially altered and there is severe degradation) is scored from 0 to 5.

The total habitat score is the sum of the 10 individual parameters. In comparison to the unmined sites, the filled/residential sites had the lowest mean total scores followed by the filled sites (see figure 72). The mined sites had a higher mean score than the unmined sites (table 15). There was some overlap of the interquartile ranges of the unmined and filled sites and only a slight overlap between the unmined and filled/residential sites. There was complete overlap between the unmined and mined sites. Although these data suggested some habitat degradation at the filled/residential and filled sites, these differences did not appear to be serious enough to impair aquatic life at most stations.

The parameter embeddedness refers to the extent to which rocks and snags are covered or sunken into the silt, sand, or mud of the stream bottom. Generally, as rocks become more embedded, less habitat is available for the aquatic organisms. This parameter was measured in the riffle where the benthic sample was collected in order to avoid any confusion with the parameter sediment deposition. The embeddedness scores indicate that among all the classes, only one site scored less than suboptimal. A filled site (MT34B) scored in the marginal category. There was overlap of the interquartile ranges between the unmined, filled, and filled/residential sites. Some overlap occurred between the mined and unmined sites but this was on the top end of the scoring range. These data indicate that for the most part there is little difference in embeddedness among the EIS classes (see figure 73).

The parameter sediment deposition measures the amount of sediment that has accumulated in pools and the changes that have occurred to the stream bottom as a result of the deposition. High levels of sediment deposition are symptoms of an unstable environment that is unsuitable for many organisms. The filled sites had the lowest mean score for this parameter followed by the filled/residential sites (see figure 74). The mined sites once again had the highest mean score. The interquartile ranges of the filled and filled/residential sites overlapped with the unmined sites. The mined class overlapped the unmined class on the high end of the scoring range.

A total of eight sites scored in the marginal category for sediment deposition. In the unmined sites, site MT50 scored high marginal. A gas line was replaced along this stream during the study period and this activity clearly increased erosion along the stream. Three filled sites (MT18, MT32, and MT57) scored at the high end of the marginal range (10) and three other filled sites (MT14, MT34B, and MT15) had scores of 8, 7, and 6, respectively. One mined site (MT106) had a marginal score of 10. One filled/residential site (MT23) scored in the poor range for sediment deposition. The pools in this stream reach were impaired by sand deposition.

The parameter epifaunal substrate considers the relative quantity and variety of natural structures in the stream, such as cobble, large rocks, fallen trees, logs and branches, undercut banks, etc. These structures provide habitat available as refugia, feeding, or sites for spawning and nursery functions. All three of the disturbed classes had some overlap with the unmined class (figure 75). The filled/residential class had the lowest mean score followed by the filled class. The mined sites had a higher mean score than the unmined sites. The filled sites as a class had epifaunal substrate characteristics comparable to natural conditions. The filled/residential class had a mean score in the suboptimal range. One of the filled/residential sites (MT55) scored in the marginal range because of bedrock dominated substrate.

The parameter bank stability measures whether the stream banks are eroded. Eroded banks indicate a problem of sediment movement and deposition, and suggest a scarcity of cover and organic input to streams. The interquartile ranges of the unmined, filled, and filled/residential classes overlap, and there is some overlap between the unmined class and the mined class, but again on the high end of the scale (figure 80). The means of the filled, filled/residential, and mined classes were higher than the unmined sites. These data indicate that there was no substantial difference between the classes. Only site MT25B (filled) scored in the marginal range (9).

The parameter bank vegetative protection measures the amount of vegetative protection afforded to the stream bank and the near-stream portion of the riparian zone. The root systems of plants and trees growing on the bank stabilize the bank, reducing erosion and increasing stability. Overhanging vegetation also provides cover for organisms and organic input to the stream. Banks that have full, natural plant growth are better for fish and macroinvertebrates than are banks without vegetation or which are shored up with rip rap, concrete, or other artificial structures. The interquartile ranges of the four EIS classes had some degree of overlap (figure 81). The filled/residential sites had the lowest mean of all the classes and one site (MT23) scored at the top end of marginal category. Only two of the six filled/residential sites scored in the optimal range. All of the filled sites scored in the optimal to suboptimal range. One unmined site (MT51) scored in the marginal range because of recent gas pipeline construction.

The parameter channel flow status measures the degree to which the channel is filled with water. All the unmined, filled, and filled/residential sites scored in the optimal range for the parameter (figure 76). The mined sites all scored in the optimal and suboptimal range. These data indicate that habitat loss due to low stream flows was not a substantial problem at any of the sites during the spring 2000 index period.

The parameter channel alteration is a measure of large-scale changes in the shape of the stream channel such as straightening, dredging, diversion, etc. The mean scores for the unmined and mined classes were in the optimal category and there was overlap of the interquartile ranges for these classes (figure 77). There was some overlap of the interquartile ranges between the unmined and filled classes and the mean score for the filled class was in the high suboptimal range. Two of the filled sites scored in the marginal category. These were sites MT34B and MT32. The filled/residential sites had the lowest mean score of all the classes but only one site (MT55) scored in less than suboptimal. Several of these sites are on larger streams and highway construction along their banks has resulted in channel alteration.

The parameter frequency of riffles is a way to measure the sequence of riffles and the heterogeneity in a stream. Riffles are very productive habitat. All four classes had mean scores in the optimal range and none of the streams scored out of the optimal range (figure 78). There were no substantial differences between the stream classes.

Table 15. Summary of Rapid Habitat Assessment Data Collected in the Spring of 2000 (mean and standard deviation)				
Habitat Parameter: mean (standard dev.)	**EIS Class**			
	Unmined (n=10)	**Filled (n=15)**	**Filled and Residences (n=6)**	**Mined (n=5)**
Total Habitat Score	155 (9.6)	148 (10.7)	144 (11.8)	159 (7.2)
Embeddedness	14.8 (2.3)	14.3 (2.6)	14.0 (1.1)	16.2 (1.3)
Sediment Deposition	14.2 (2.6)	12.2 (3.6)	12.7 (4.1)	15.2 (3.1)
Epifaunal Substrate	16.3 (2.8)	15.6 (2.7)	13.5 (3.7)	18.0 (1.2)
Channel Flow Status	17.5 (0.9)	17.9 (1.0)	17.8 (1.5)	15.6 (1.9)
Channel Alteration	16.7 (0.9)	14.7 (3.1)	13.3 (2.5)	16.0 (1.9)
Frequency of Riffles	17.9 (1.1)	17.5 (1.0)	17.2 (0.8)	18.2 (0.8)
Velocity Depth Regimes	12.8 (3.0)	12.6 (3.0)	16.0 (1.4)	11.2 (2.7)
Bank Stability	14.5 (2.8)	15.0 (2.4)	15.2 (1.9)	16.6 (0.9)
Bank Vegetative Protection	15.1 (2.3)	14.8 (2.0)	13.3 (3.1)	15.6 (1.9)
Riparian Vegetation Zone	15.2 (2.9)	13.9 (2.9)	11.0 (4.0)	16.2 (1.9)
Condition Categories for Individual Parameters: 20-16 Optimal 15-11 Suboptimal 10-6 Marginal 5-0 Poor				

The parameter velocity/depth combinations measures the patterns of velocity and depth in the stream reach. The best streams will have all four velocity/depth patterns present (slow-deep, fast-deep, slow-shallow and fast-shallow). There was overlap of the interquartile ranges between the unmined, filled, and mined classes and some overlap between the unmined and filled/residential classes (figure 79). The mean score for the filled/residential sites was 16, while the mean scores for the other classes ranged from 11.2 to 12.8. Many of the streams that scored low in the unmined, filled, and mined classes are small streams and are naturally limited because they often do not have deep water. Several of the filled/residential sites are located on larger streams which are more complex and more likely to have deep water.

The parameter riparian vegetation zone width measures the amount of vegetative protection afforded to the stream bank and the near-stream portion of the riparian zone. The interquartile ranges between the unmined and mined classes overlapped and there was some overlap of the unmined class with the filled and filled/residential classes (figure 82). The filled/residential and filled sites had the lowest mean scores, 11.0 and 13.9, respectively. The filled/residential sites were often located close to highways which results in a loss of vegetation and the filled sites were sometimes located close to haul roads, which had the same effect.

6.3 Substrate Size and Composition

Riffles and runs are critical for maintaining a variety and abundance of aquatic insects in high gradient streams. More diverse invertebrate assemblages are generally associated with larger substrates which provide lots of interstitial spaces and surface area (Barbour et al 1999, Hynes 1970, Kaufmann et al 1999, Ward 1992). Excessive amounts of sediment in a stream can fill in interstitial spaces, reducing the habitat available for the organisms. High levels of sediment deposition are also symptoms of an unstable and continually changing environment that is unsuitable for many organisms. In the MTM/VF region in southern West Virginia, many activities can destabilize watersheds and increase sediment supply, including logging and mining. We measured substrate size and composition in order to determine if excessive sediment was causing the biological impairment observed in the filled and filled/residential classes.

Numeric scores were assigned to the substrate size classes that are proportional to the logarithm of the midpoint diameter of each size class (table 16). The mean substrate size class was calculated as the arithmetic mean of the numerically transformed size classes. The logarithmic nature of the substrate size classes specified in EMAP methods makes these mean size class scores proportional to the geometric mean substrate diameter. Based on assigning geometric midpoint diameters to each particle class, the following relationship was derived to transform mean diameter class scores into estimates of the $\log_{10}$ of mean substrate diameter in millimeters: If mean substrate size class score was less than or equal to 2.5 then $\log_{10}$ of mean substrate diameter was calculated as (-4.61 +(2.16 *mean diameter class)); if mean substrate size class score was greater than 2.5 then $\log_{10}$ of mean substrate diameter was calculated as (-1.78 +(0.960 *mean diameter class)) (Kaufmann et al 1999). The reach level mean substrate diameter in millimeters was derived by taking the antilog of these equations.

The reach level percentages of sands and fines (diameter less than or equal to 2 mm) were derived from the frequency of particles in these two size classes divided by the 55 total particle measurements. For example, if 5 of the measurements in the reach were classified as sand or fines, then the percentage of the substrate less than or equal to 2 mm would be 5/55*(100) or approximately 9%.

Table 16. Substrate Size Classes and Class Scores			
Class	**Size**	**Class Score**	**Description**
Bedrock	>4000 mm	6	Bigger than a car
Boulder	>250-4000 mm	5	Basketball to car
Cobble	>64-250 mm	4	Tennis ball to basketball
Coarse Gravel	>16-64 mm	3.5	Marble to tennis ball
Fine Gravel	>2-16 mm	2.5	Ladybug to marble
Sand	>0.06-2 mm	2	Gritty between fingers
Fines	<0.06 mm	1	Smooth, not gritty

The substrate size data indicate that the mean substrate size class scores and the mean calculated substrate particle sizes were smaller in the filled sites than in the unmined sites (table 17). The filled/residential streams also had substrates which were smaller than the unmined sites. The mined sites had the largest substrate of all the sites. The interquartile range of the unmined classes overlapped almost completely with the interquartile ranges of the filled and filled/residential classes indicating that the differences between the classes were not substantial (figures 83 and 84). The outliers included two sites with natural bedrock substrates (sites MT104 (filled) and MT55 (filled/residential)). Site MT23 (filled/residential) had the smallest substrate of all the sites with a mean substrate size in the small gravel range.

The filled and filled/residential class streams contained a greater mean percentage of sands and fines than did the unmined streams. The mined streams contained the lowest amount of sands and fines (table 17 and figure 85). There was substantial overlap of the interquartile ranges between the unmined and filled classes but the data also indicate signs of fining in some of the individual filled streams. There was also some overlap of the interquartile ranges between the unmined and filled/residential classes indicating mean conditions in the two classes might not be substantially different. Again, though, there were indications of fining in some of the individual streams in the filled/residential class.

In general, the measured substrate characteristics of the filled, filled/residential, and mined classes were not substantially different from the unmined class. However, there were specific stations within these EIS classes that were substantially different. Site photographs taken during the field work also illustrate these conclusions. It should be noted that many of the filled sites were established in first and second order streams in order to limit the potential stressors in the watershed to the valley fills. Our data indicate that the valley fills do not seem to be causing excessive sediment deposition in the first and second order streams that were sampled. Our results should not be extrapolated to reaches downstream in these watersheds or to higher order streams.

Table 17. Summary of Substrate Size and Composition Data Collected in the Spring of 2000 (mean and standard deviation)				
Substrate Parameter: mean (standard dev.)	**EIS Class**			
	Unmined	**Filled**	**Filled/residential**	**Mined**
Mean Substrate Size Class	3.65 (0.31)	3.50 (0.45)	3.55 (0.84)	3.98 (0.30)
Calculated Mean Substrate Size (mm)	53 (coarse gravel)	38 (coarse gravel)	42 (coarse gravel)	109 (cobble)
% < or = to 2mm (% that is sand and fines)	16.9 (9.9)	20.7 (12.9)	29.7 (24.1)	8.0 (9.2)

7.0 ASSOCIATIONS BETWEEN BIOLOGICAL CONDITION OF STREAMS AND SELECTED PHYSICAL/CHEMICAL PARAMETERS

In the previous section, the physical and chemical conditions of the streams and stream classes were described using direct measurements of water quality, physical habitat, and substrate size and composition. We explored differences between the classes using the unmined class as a control group. In this section, we explore associations between the spring 2000 benthic metrics and median conductivity, total habitat scores, sediment deposition scores, and % sand and fines. These physical and chemical parameters were either substantially different between the EIS classes, appeared to be different at several individual sites, or they were measured at levels that could be considered limiting or harmful to aquatic life. We calculated the median conductivity over the study period at each of the sites and used that statistic to represent longer term conductivity values. We used the spring 2000 total habitat scores, sediment deposition scores, and % sand and fines estimates.

7.1 Correlation Analysis

Correlation analysis is used to determine the relationship between two variables without specifying a dependent and independent variable. That is, there is no causal relationship assumed.

We used Pearson Product Moment Correlation to explore associations between the benthic metrics and the physical and chemical parameters. The results of these tests are in shown in table 18. The correlation coefficient, r, quantifies the strength of the relationship between the variables. The values of r can vary between -1 and +1. A correlation coefficient near +1 indicates that there is a strong positive relationship between the two variables, with both always increasing together. A correlation coefficient near -1 indicates there is a strong negative relationship between the two variables, with one always decreasing as the other increases. A correlation coefficient of zero indicates no relationship between the two variables.

The P value is the probability of being wrong in concluding that there is a true association between the variables. The smaller the P value, the greater the probability that the variables are correlated. Traditionally, you can conclude there is a true association between the variables when $P < 0.05$.

Generally, all of the benthic metrics were associated positively or negatively, as expected to the potential stressors. The Stream Condition Index (SCI), Total Taxa, EPT, %EPT, Mayfly Taxa, and % Mayflies all decreased with increasing conductivity and increasing % sand and fines (increasing degradation). These same metrics all increased with increasing total habitat scores and increasing sediment deposition scores (decreasing degradation). The metrics HBI, % Two Dominant, and % Chironomidae all increased with increasing conductivity and % sand and fines. These metrics all decreased with increasing total habitat scores and sediment deposition scores.

Table 18 . Strength of Associations Between Benthic Metrics and Physical/Chemical Variables Pearson Product Moment Correlation Matrix				
r (correlation coefficient) p value	**Median Conductivity (uS/cm)**	**Total Habitat Score**	**Sediment Deposition Score**	**% < or = to 2mm (% sand and fines)**
WVSCI	-0.810 <0.01	0.459 <0.01	0.411 0.013	-0.296 0.079
Total Taxa	-0.699 <0.01	0.413 0.012	0.483 <0.01	-0.323 0.055
EPT	-0.783 <0.01	0.530 <0.01	0.601 <0.01	-0.378 0.02
%EPT	-0.753 <0.01	0.483 <0.01	0.433 <0.01	-0.369 0.03
HBI	0.672 <0.01	-0.360 0.031	-0.318 0.06	0.278 0.10
%2Dom	0.760 <0.01	-0.371 0.026	-0.384 0.02	0.194 0.26
%Chiro	0.511 <0.01	-0.219 0.200	-0.145 0.4	0.198 0.25
Mayfly Taxa	-0.812 <0.01	0.287 0.09	0.363 0.03	-0.183 0.29
% Mayflies	-0.780 <0.01	0.511 <0.01	0.429 <0.01	-0.320 0.06
Median Conductivity		-0.535 <0.01	-0.547 <0.01	0.348 0.04
Total Habitat Score			0.695 <0.01	-0.658 <0.01
Sediment Deposition Score				-0.756 <0.01
n = 36 for all pairs.				

The strengths of the associations varied ® values), as did the significance of the associations (P values). Generally, the strongest associations and the smallest P values were related to associations between the benthic metrics and the median conductivity. The associations between the benthic metrics and total habitat score and between the benthic metrics and the sediment deposition scores had lower correlation coefficients, and larger P values. The associations between the benthic metrics and the % sand and fines measurements had the lowest correlation coefficients and the highest P values. Many of the P values for this stressor were greater than the significance threshold of 0.05.

The Stream Condition Index (SCI) and the Mayfly Taxa metric were the benthic metrics most strongly correlated to median conductivity ($r = -0.810$ and $r = -0.812$) respectively. Many of the other metrics also had strong correlations.

It should be noted that we used a single habitat approach to sampling the benthic community; we only sampled riffles. The total habitat scores, sediment deposition scores and % sand and fines reflect habitat degradation in the entire reach, including pool habitat. Therefore, we would not necessarily expect strong correlations between benthic condition and habitat degradation measured throughout the reach since the benthic community was not sampled in all habitats.

It is also important to note that conductivity was negatively and quite strongly correlated to the total habitat score and the sediment deposition scores. Conductivity is often used as a general indicator of watershed disturbance. Our data indicate that watersheds with elevated conductivity are also likely to have degraded stream habitats. Disturbance in a watershed rarely impacts only water quality or only habitat.

Total habitat scores were strongly correlated with sediment deposition scores and % sand and fines. Sediment deposition scores were strongly correlated to % sand and fines. These parameters are all related: sediment deposition was one of the few habitat parameters that scored marginally at several sites and directly affects the total habitat score. The measurement of % sand and fines is simply a more quantitative estimate of sediment deposition.

7.2 Regression Analysis

Regression analysis involves one dependent and one independent variable. Regression analysis determines the relationship between two variables in cases in which the magnitude of one variable, the dependent variable or Y, is a function of the magnitude of the second variable, the independent variable or X. In order to determine how well some of these physical and chemical measures predict the benthic metrics (or in other words, stream condition), we used least squares simple linear regression. Table 19 shows the coefficient of determination values (r2) for each pair of variables. The coefficient of determination indicates how much of the variation in the observations can be explained by the regression equation. The largest value r2 can assume is 1, a result that occurs when all of the variation is explained by the regression, or all of the data points fall on the regression line.

Several of the variables failed either the normality test or the constant variance test of the linear regression and had to be transformed. The normality test requires that the source population is normally distributed around the regression line. Failure of the normality test can indicate the presence of outlying data points or an incorrect regression model (the model may be non linear). The constant variance test requires that the variance of the dependent variable (in our case the benthic metrics) in the source population is constant regardless of the value of the independent variable (in our case the physical and chemical measurements).

Table 19 . Least Squares Linear Regression Coefficients of Determination Non-Transformed Data				
r2 (coefficient of determination) values	**Median Conductivity (uS/cm)**	**Total Habitat Score**	**Sediment Deposition Score**	**% < or = to 2mm (% sand and fines)**
WVSCI	**0.656**	0.211	**0.169**	**0.088***
Total Taxa	**0.489**	**0.170**	0.233	0.104*
EPT	0.614	0.281	0.361	0.143
%EPT	0.567	0.233	**0.187**	0.136
HBI	0.451	0.130	0.101*	**0.077***
%2Dom	0.578	0.137	0.147	0.038*
%Chiro	**0.261**	0.048*	**0.021***	**0.039***
Mayfly Taxa	0.660	0.082*	0.132	0.033*
% Mayflies	0.608	0.261	0.184	**0.102***

n = 36 for all pairs.
r2 values in bold indicate that this data set failed either the normality test or the constant variance test and had to be transformed to use the linear regression model. See table 20.
*: r2 values marked with an asterisk had a P>0.05.

When the variables failed one or both of these tests, we used the transformation log (x) to transform some of the variables (SCI, Total Taxa, HBI, median conductivity, sediment deposition and total habitat scores). We used an arcsin square root transformation to transform the percentage metrics and measures (% Mayflies, % EPT, % Chironomidae, and % sand and fines). The percentage metrics and measures were first converted to proportions (values between 0 and 1) before being transformed. The coefficient of determination (r2) values for those pairs of variables which failed the assumptions of the test and had to be transformed are shown in table 20. For some of the variables, the standard transformations were not successful in resolving the normality and equal variance problems of the data sets (SCI vs. % sand and fines, Total Taxa vs. median conductivity, and Total Taxa vs. total habitat scores). The coefficients of determination for the transformed data sets are shown in table 20.

The non-transformed and transformed regressions for the Stream Condition Index (SCI) against conductivity are shown in figures 86 and 87. The non-transformed and transformed regressions for the SCI against sediment deposition scores are shown in figures 88 and 89. The non-transformed regressions for the SCI against total habitat scores and % sand and fines are shown in figures 90 and 91. The regression equations are provided in the figures. It should be noted that P was greater than 0.05 for the SCI vs. % sand and fines regression.

Table 20 . Least Squares Linear Regression Coefficients of Determination Transformed Data				
r2 (coefficient of determination) values	**Median Conductivity (uS/cm)**	**Total Habitat Score**	**Sediment Deposition Score**	**% < or = to 2mm (% sand and fines)**
WVSCI	0.560	N/A	0.199	**
Total Taxa	**	**	N/A	N/A
EPT	N/A	N/A	N/A	N/A
%EPT	N/A	N/A	0.222	N/A
HBI	N/A	N/A	N/A	0.070*
%2Dom	N/A	N/A	N/A	N/A
%Chiro	0.264	N/A	0.040*	0.036*
Mayfly Taxa	N/A	N/A	N/A	N/A
% Mayflies	N/A	N/A	N/A	0.124

n = 36 for all pairs.
*: r2 values marked with an asterisk had a P>0.05.
**: transformations did not solve normality or constant variance problems in data set.
N/A: data did not require transformations (see table 19).

Figure 86 and the regression equation for SCI and median conductivity suggest that in order for a site to score 70 or better (good or very good condition), the median conductivity must be 426 uS/cm or less. Figure 87 and the regression equation for SCI and transformed median conductivity suggest that in order for a site to score 70 or better (good or very good condition), the median conductivity must be 230 uS/cm or less. We believe the higher median conductivity concentration (426 uS/cm) is a more realistic threshold where adverse impacts to the biota may occur.

There were no apparent trends, or very weak trends between the SCI scores and sediment deposition scores, total habitat scores, and % of the substrate that was sand and fines (see figures 88, 89, 90 and 91). Sites with similar physical characteristics (i.e. similar sediment deposition scores, total habitat scores, or % sand and fines) had widely varying Stream Condition Index scores. Again, it is important to remember that we sampled the benthic community in the riffles only, and the parameter % sand and fines measures excess sediment deposition throughout the reach, including pools. Keeping in mind the implications of the use of the single habitat protocol to sample the benthic community, we still believe the data indicate most of the difference in the biological condition of these streams can be explained by water quality.

8.0 CUMULATIVE SITES AND SEDIMENT CONTROL STRUCTURE

This study considered three objectives. This study only provides limited data to address the second and third objectives. Our findings on these objectives are summarized below, but should be treated with caution since they are based on limited data.

Objective 2. Characterize conditions and describe any cumulative impacts that can be detected in streams downstream of multiple fills.

We used the WVDEP SCI scores to determine overall differences in biological condition upstream and downstream of four MTM/VF operations (table 18). A monitoring site was established as the upstream control, and a site was established as the downstream control. This was a difficult objective to explore. In three of the cases (Mud River, Spruce Fork, and Island Creek), there were potential stressors upstream of the upstream control site and in between the upstream and downstream control sites not related to the MTM/VF operations of interest. The upstream control sites in the Mud River and in Spruce Fork were impaired and the upstream control site in Cow Creek was not impaired. In one watershed (Clear Fork), this objective could not even be explored because several of the headwater streams in the watershed had been filled by the MTM/VF operation. The only substantial differences between the upstream and downstream sites was observed in Cow Creek (Island Creek Watershed). Conditions were much worse at the downstream site compared to the upstream site. The observed impairment could be caused by several stressors, including mining and residential land use.

Two of the watersheds are larger watersheds and the monitoring sites were located to compare conditions upstream and downstream of multiple fills. In the case of Mud River, site MT01 was established upstream of the MTM/VF operations and site MT23 was located downstream of these operations. Biological conditions degraded very slightly from upstream to downstream in the spring 1999 dataset. The upstream site on the Mud River could not be sampled in the summer of 1999 due to the drought. In the fall 1999, winter 2000, and spring 2000 datasets, the conditions improved from upstream to downstream. The difference observed in the fall 1999 dataset is the only difference that appears to be significant.

In the case of Spruce Fork, site MT40 was established upstream of the MTM/VF operations and site MT48 was established downstream of the operations. Biological conditions improved from upstream to downstream in the spring1999, summer 1999, fall 1999, and winter 2000 datasets. Conditions degraded from upstream to downstream in the spring 2000 dataset.. The difference observed in the spring 1999 dataset is the only difference that appears to be significant.

In both the Mud River and Spruce Fork watersheds, there are stressors other than mining in the reach between the sampling locations (residences and roads). In both watersheds, there are a few unmined tributaries that contribute flow to the watershed between the sampling locations.

Table 18. Summary of Biological Condition at Upstream and Downstream Control Sites			
Season	**SCI Score and Condition Class at Upstream Station**	**SCI Score and Condition Class at Downstream Station**	**Change in SCI Score from Upstream to Downstream**
Mud River Watershed			
	MT01	MT23	
Spring 1999	49 fair	45 fair	-4
Summer 1999	N/A	58 fair	N/A
Fall 1999	34 poor	68 fair	+34
Winter 2000	45 poor	53 fair	+8
Spring 2000	37 poor	42 fair	+5
Spruce Fork Watershed			
	MT40	MT48	
Spring 1999	38 poor	57 fair	+19
Summer 1999	49 fair	59 fair	+10
Fall 1999	53 fair	63 fair	+10
Winter 2000	29 poor	35 poor	+6
Spring 2000	43 poor	35 poor	-7

Table 18. Summary of Biological Condition at Upstream and Downstream Control Sites			
Season	**SCI Score and Condition Class at Upstream Station**	**SCI Score and Condition Class at Downstream Station**	**Change in SCI Score from Upstream to Downstream**
Twentymile Creek Watershed			
	MT91	MT86	
Spring 1999	73 good	81 good	+8
Summer 1999	67 fair	58 fair	-10
Fall 1999	77 good	77 good	no change
Winter 2000	78 good	74 good	-4
Spring 2000	85 very good	77 good	-8
Island Creek Watershed			
	MT52	MT55	
Spring 1999	82 very good	27 poor	-55
Summer 1999	63 fair	53 fair	-10
Fall 1999	71 good	34 poor	-37
Winter 2000	86 very good	23 very poor	-63
Spring 2000	88 very good	40 poor	-48
N/A: not applicable. The upstream site could not be sampled due to the drought.			

Two of the watersheds are smaller watersheds and sites were located to compare conditions upstream and downstream of the fills. In Rader Fork (Twentymile Creek watershed), site MT91 was established upstream of the operations and MT86 was established downstream of the operations. Biological conditions improved slightly from upstream to downstream in the spring of 1999. In the summer 1999, winter 2000 and spring 2000 datasets, conditions degraded slightly from upstream to downstream. There was no change in the stream condition index in the fall of 1999. None of these differences appear to be substantial. Rader Fork has no residences and there is mine drainage treatment on two of the fills influencing the stream.

In Cow Creek (Island Creek watershed), site MT52 was established upstream of the MTM/VF operations, and MT55 was established downstream of the operations. There is one very small fill upstream of site MT52, but it was built to face up the entrance to an underground mine and is not a typical valley fill. Biological conditions degraded from upstream to downstream in every season. Except for the difference observed in the summer 1999 dataset, these differences are substantial. There are several residences between the upstream and downstream sites in this reach. The impairment observed at site MT55 could be due to several stressors, including mining and residential land use.

In both Cow Creek and Rader Fork, there are no unmined tributaries that contribute flow to the watersheds between the sampling locations.

This objective could not be explored in the Clear Fork watershed as Toney Fork had several valley fills in its headwaters, and there was no "upstream" control.

Objective 3. Characterize conditions in sediment control structures (ditches) on MTM/VF operations.

We considered several sediment control structures as candidate monitoring sites. However, many of the sites were not reconstructed streams, but ponds or dry ditches filled with boulder-sized rip-rap. Only one sediment control structure was identified as having flowing water and could be sampled. Since only one such site was sampled, this study provides only limited information to characterize conditions in sediment control structures on MTM/VF operations.

Site MT24, located in a sediment control ditch on a surface mine, was more degraded than any site sampled in the study. The SCI score at this site was in the poor or very poor range over all five seasons. The entire drainage area of this site has been disturbed by mining, and the ditch does not represent natural stream habitat. This was also the only site in the study where we observed an exceedance of a water quality criterion. In the summer 1999 index period, we measured a dissolved oxygen concentration of 3.6 mg/l, which was less than the required minimum of 5 mg/l.

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APPENDIX 1. SITE ATTRIBUTES

Mud River Watershed

The headwaters of the Mud River rise in Boone County and flow in a northwesterly direction into Lincoln County. Most of the watershed lies in Lincoln County. The headwaters of the Mud River watershed do not lie in the primary mountaintop mining area as described by the West Virginia Geological and Economic Survey (figure 1). In this watershed, the area of concern is a strip of land approximately five miles wide that runs perpendicular to the watershed and straddles the Boone and Lincoln County line. The remaining downstream watershed is out of the area of concern.

From the headwaters to the northwestern boundary of the primary mountaintop mining area, the watershed lies in the Cumberland Mountains of the Central Appalachian Plateau (subecoregion 69d) (Woods et al 1999) (figure 2). Woods et al describe the physiography as being unglaciated, dissected hills and mountains with steep slopes and very narrow ridge tops. The geology is described as being Pennsylvania sandstone, siltstone, shale, and coal of the Pottsville Group and Allegheny Formation. The primary land use is forest with extensive coal mining, logging, and gas wells. Some livestock farms and scattered towns exist in the wider valleys. Most of the low-density residential land use is concentrated in the narrow valleys.

The remainder of the watershed lies in the Monongahela Transition Zone of the Western Allegheny Plateau (subecoregion 70b). The Monongahela Transition Zone is outside the primary area of mountaintop mining. However it is mined and there are fills associated with this mining. This area is unglaciated with more rounded hills, knobs, and ridges compared to the dissected hills and mountains with steep slopes and very narrow ridge tops found in the Central Appalachian Plateau (Woods et al 1999). Land slips do occur in the Monongahela Transition Zone. The geology is Permian and Pennsylvanian interbedded sandstone, shale, limestone and coal of the Monongahela Group and less typically the Waynesboro Formation. The primary land use is forest with some urban, suburban, and industrial activity in the valleys. There is also coal mining and general farming in this region.

Site MT01 was established on the Mud River (see figure 3). The county road and residences are the major disturbances in this part of the watershed. The Mud River watershed from its headwaters to site MT01 has seen very little mining activity. One small area of contour surface mining and some drift punch mining have taken place in Bearcamp Branch. Based on the USGS topographic map, the estimated area disturbed by mining is 16 acres, or about 0.8 percent of the watershed area upstream of site MT01. In addition, this mining occurred sometime prior to 1962. This site served as the upstream cumulative control for the Hobet MTM/VF complex. Site MT01 was classified as mined/residential. This site was not used in the final analysis of the classes since it has both historical mining and residences upstream.

Site MT02 was established on Rushpatch Branch upstream of all residences and a small farm. There is no history of mining in this watershed. There is evidence of logging and gas well development. This site was classified as unmined.

Site MT03 was established on Lukey Fork. This site was classified as an unmined site and logging is the only known disturbance that has occurred upstream of this site. This site was established well above the mouth of Lukey Fork because three valley fills were being constructed on the lowest three unnamed tributaries on the West side of Lukey Fork. In addition, a gas transmission line was relocated through the lower part of the watershed. These activities are related to the active Westridge Mine.

Site MT13 was established on the Spring Branch of Ballard Fork. Site MT13 was classified as unmined, and there is little evidence of human disturbance in the watershed, with the exception of historical logging activity.

The entire north side of Ballard Fork has been mined. There are ten fills on the north side of the watershed. The south side has not been mined. Site MT14 was established on Ballard Fork downstream of eight fills. Three permits were issued for this mining in 1985, 1988, and 1989.

Mountaintop mining has occurred on all of the ridges in the Stanley Fork watershed. There are a total of six fills within the Stanley Fork drainage. Both upper fills are large, with one fill on an unnamed tributary being about 1.3 miles long. Site MT15 was established on Stanley Fork downstream of all six fills. These mining permits were issued in 1988, 1989, 1991, 1992, and 1995.

A sediment control structure on top of the mining operation was also sampled (site MT24). This structure is associated with the 1.3 mile-long fill on the unnamed tributary to Stanley Fork. The structure is a series of wetland cells with flowing water in between the cells. This stream is located at the interface of the valley fill and overburden and is directly on the pavement of the lowest coal seam mined. This site was not used in the final analysis of the classes since it does not represent natural stream habitat. This site was classified as a sediment control structure.

Two valley fills are located in the Sugartree Branch watershed. One fill is small, but the other one is about one mile long. Site MT18 was established downstream of both of these fills. The mining permits were issued in 1992 and 1995.

Site MT23 was established on the Mud River downstream of the entire Hobet complex. Mining activity upstream includes both active and inactive surface mines and one active underground mine. This site was used as the cumulative downstream site for the Mud River Watershed. This site was established downstream of a total of 26 completed or under construction fills. This site was classified as filled/residential.

In the spring of 2000, another site was added in the Mud River Watershed. This site (MT106) was established on an unnamed tributary to Sugartree Branch and has historical surface mining but no valley fills in its watershed. This site was classified as mined.

Spruce Fork Watershed

The Spruce Fork watershed drains portions of Boone and Logan Counties. The stream flows in a northerly direction to the town of Madison where it joins Pond Fork to form the Little Coal River. About 85 to 90 percent of the watershed resides in the primary mountaintop mining region (figure 1). Only the northwest corner lies outside this region. The entire watershed lies within subecoregion 69d (Cumberland Mountains) (figure 2). The watershed has been the location of surface and underground mining activity for many years, and numerous subwatersheds have been disturbed.

Site MT39 was established on White Oak Branch (figure 4). White Oak Branch is a tributary with no surface mining, entering Spruce Fork from the east, not far downstream of the former Kelly Mine. This site was classified as unmined.

Site MT40 was established on Spruce Fork and served as the upstream control for the bulk of the Daltex MTM/VF operations. The watershed above this point is anything but pristine. Again, mining has been an ongoing activity for many years. Based on the information available (Cumulative Hydrologic Impact Analysis (CHIA) maps, topographic maps, and personnel knowledge), there are seven surface mine valley fills and three fills associated with refuse disposal located upstream of this sampling point. This site was classified as filled/residential.

Oldhouse Branch enters Spruce Fork in the town of Blair, from the east. Site MT42 was established on this tributary, well upstream of any residences. This tributary has no known history of surface mining and was classified as unmined.

Pigeonroost Branch is the next downstream tributary to Spruce Fork and enters the river from the east. Site MT45 was established on Pigeonroost Branch, well upstream of any residences. Some contour mining has occurred in the headwaters of this watershed. Based on permit information and topographic maps, this mining was done sometime between 1987 and 1989. Approximately 75 acres, or about 6.7 percent of the watershed, were disturbed. This site was classified as mined.

Site MT32 was established on Beech Creek downstream of five valley fills. Beech Creek enters Spruce Fork from the west. The watershed upstream of this site has been extensively mined over the years. Contour mining occurred prior to 1963 and has continued until the recent past. Mountaintop mining began in the late 1980s. Underground mining activity has also occurred in the watershed. This site was classified as filled.

MT34B was established on the Left Fork of Beech Creek. This watershed has also been extensively mined over the years by both underground and surface mining methods. There is evidence of contour mining prior to 1963 and continuing through 1989. It appears mountaintop mining began in the late 1980s and continued into 1999. Reclamation is still active in the watershed. Based on the information available, we estimate that greater than 80 percent of the watershed has been disturbed by mining activities. This site was classified as filled.

Site MT48 was established on Spruce Fork downstream of all the Daltex operations except for those activities on Rockhouse Creek. This site was used as a cumulative downstream site for Spruce Fork. To the best of our knowledge, we believe there are 22 valley fills upstream of this site. There are several small communities upstream of this site including Blair, Spruce Valley, Five Block, and Sharples. This site was classified as filled/residential.

Site MT25B was established on Rockhouse Creek below the sediment pond of a large valley fill. Over the years, greater than 90 percent of the watershed has been disturbed by mining activities. The valley floor was mined and some contour mining was done prior to 1963. The mountaintop mining permit for this watershed was issued in 1986. This mining impacted nearly the entire watershed above the sampling site, including the older mine workings. The mainstem of Rockhouse Creek has a low U-shaped fill. The side tributaries are more typical with the fills extending up to the pavement of the lowest coal seam mined. This site was classified as filled.

Clear Fork Watershed

Clear Fork flows in a northwesterly direction to its confluence with Marsh Fork where they form the Big Coal River near Whitesville. The entire watershed lies within Raleigh County. All but a tiny part of the watershed is within the primary mountaintop mining area and is within subecoregion 69d (Cumberland Mountains) (figures 1 and 2). The coal mining industry has been active in this watershed for many years. Both surface and underground mining have occurred in the past and continue today. Two subwatersheds, Sycamore Creek and Toney Fork, were sampled as part of this survey.

There are no unmined sites in Clear Fork. Site MT79 was established on Davis Fork, a tributary to Sycamore Creek (see figure 5). Site MT79 was initially classified as unmined, but further investigation revealed mining activity in the headwaters. This site was classified as mined.

Site MT78 was established on Raines Fork, also a tributary to Sycamore Creek. This watershed has been subjected to shoot and shove contour surface mining prior to 1965. The term "shoot and shove" applies to pre-law mining practices. This practice was primarily narrow bench contour mining where the spoil material was handled by shoving it over the side of the hill. There was little or no reclamation associated with this practice. Approximately 20 percent of this watershed has been disturbed in the past. There is evidence that the ridge tops have also been underground mined. This site was classified as mined.

Site MT81 was established on Sycamore Creek upstream of the confluence with Lem Fork. Part of the watershed upstream of this site has been contour mined using the old shoot and shove method. About 12 percent of the watershed was impacted by contour mining prior to 1965. Underground mining has also occurred in the ridge tops. A treatment plant for permit # U-3024 is located on the valley floor above MT81. The effluent from the mine is piped from the ridge top to the treatment plant. The plant treats the effluent with sodium hydroxide in order increase the pH and remove metals. On our field visits to the stream, we did not see a direct discharge to the stream. This site was classified as mined.

Site MT75 was established on Toney Fork downstream of five valley fills. Mountaintop mining occurred on both sides of the subwatershed upstream of this sampling point. There are numerous residences upstream of this point, which is unusual for a valley this size. The spring and summer samples were collected at this site. Site MT70 was later established downstream of site MT75 because of sampling and logistical constraints. The fall 1999, winter 2000 and spring 2000 samples were collected at MT70. MT70 was established about 0.6 miles downstream of MT75, downstream of one additional valley fill and some additional residences. Both sites were classified as filled/residential.

Site MT69 was established on Ewing Fork about 0.35 miles above its confluence with Toney Fork. Some contour mining was done in this watershed prior to 1965. About three percent of the watershed was disturbed by this activity. There are also indications that underground mining has occurred in the past. This site was not used in the analysis of the classes since it has both mining activity and a residence in its headwaters.

Site MT64 was established on Buffalo Fork. Some contour mining has occurred in this watershed prior to 1965 and prior to mountaintop mining. The mountaintop mining in this watershed was permitted in 1992 and 1993. There are five valley fills upstream of this site associated with these permits. Reclamation work is still under way on the south side of the watershed. There are no residences in the watershed above the sampling point. There is a small amount of pasture upstream of the sampled site. This site was classified as filled.

Site MT62 was established on Toney Fork and served as the cumulative downstream site for Toney Fork. MT62 was established downstream of the confluence of Toney Fork and Buffalo Fork, downstream of all eleven fills in the watershed and numerous residences. There is also a small amount of pasture in the Buffalo Fork drainage upstream of MT62. This site was classified as filled/residential.

Twentymile Creek Watershed

Twentymile Creek drains portions of four counties: Clay, Fayette, Kanawha, and Nicholas. It flows generally to the southwest where it joins the Gauley River at Belva, West Virginia. Except for a small area on the western edge of the watershed, it is within the primary mountaintop mining area, and it all lies within subecoregion 69d (Cumberland Mountains) (figures 1 and 2). The watershed upstream of Vaughn is uninhabited. Logging, mining, and gas wells are the primary activities upstream of Vaughn. There has been a limited amount of old mining in the watershed above Vaughn but the majority of the mining activity is more recent. Downstream of Vaughn there are numerous residences and some small communities.

Site MT95 was established on Neil Branch, a tributary of Twentymile Creek (figure 6). Neil Branch is located in the middle of the Twentymile Creek watershed. At the beginning of this study, we believed that the Neil Branch watershed was entirely forested with no recent logging or other activities. During the study we heard that some logging was occurring in Neil Branch, but we have not personally confirmed this. This site was classified as unmined.

Site MT91 was established on Rader Fork upstream of Neff Fork and was classified as an unmined site. There is an active haul road that runs adjacent to this stream. There is considerable coal truck traffic on this road which is a potential impact to the stream. Alex Energy Inc. has applied for a surface mine permit which would include the headwaters of Laurel Run, a tributary to Rader Fork.

Site MT87 was established on Neff Fork. There are three valley fills upstream of this sampling site, two in the headwaters of the mainstem and one on a tributary entering from the northeast. A mine drainage treatment plant is in place below the two mainstem fills and uses sodium hydroxide to increase the pH and remove metals. This site was classified as filled.

Site MT86 was established on Rader Fork about 500 feet upstream of its confluence with Twentymile Creek. This site was established downstream of both MT87 and MT91. This site was classified as filled.

Three sampling sites were established on Hughes Fork in the southern portion of Twentymile Creek watershed. This watershed is unique in that there is only one sediment pond for all fills in the watershed instead of one for each individual fill. The most upstream site (MT103) was established downstream of six completed fills. Site MT98, downstream of MT103, was established downstream of eight fills. One of the eight fills has not been completed. Site MT104 was established downstream of the large sediment pond which serves all eight fills. All three sites were classified as filled.

Island Creek Watershed

Island Creek flows in a generally northerly direction to Logan where it enters the Guyandotte River. The entire watershed is confined to Logan County. All but the northern part of the watershed lies in the primary mountaintop mining area and the entire watershed is located in subecoregion 69d (Cumberland Mountains) (figures 1 and 2). Extensive underground mining has occurred in the watershed for many years. As these reserves have been depleted and economics have changed, surface mining has taken on a bigger role in the watershed.

Two unmined sites (MT50 and MT51) were initially established in the Island Creek watershed (figure 7). They were both established on Cabin Branch. This watershed is leased to a hunting club and access is limited. There is a gas line and jeep trail running adjacent to the stream, and one gas well at the confluence of Cabin Branch and Jacks Fork. Site MT50 was established in the headwaters of the mainstem just upstream of the confluence with Jacks Fork and a gas well. MT51 was established further downstream and nearer the mouth of Cabin Branch. The watershed area at site MT51 is roughly twice as large as at site MT50.

In the spring of 2000, we added another unmined site in the Island Creek watershed. Site MT107 was established on Left Fork, upstream of the influence of the fills. We established this unmined site to provide a closer watershed reference site for the Cow Creek sites. Three valley fills have been proposed upstream of this site.

Site MT52 was established near the headwaters of Cow Creek, upstream of all fills associated with surface mining. There has been limited disturbance in the headwaters. Approximately 1.3 percent of the watershed was disturbed by an entry for an underground mine. The entry was faced up and a small fill with a sediment pond was created in the headwaters of Cow Creek. This site was classified as filled.

A single valley fill resides in the headwaters of Hall Fork of Left Fork. Site MT57B was initially established directly downstream of the sediment pond for the valley fill. Because of access and sampling constraints, the site was moved downstream nearer the mouth of Hall Fork in the fall of 1999. The new location was named site MT57. The spring and summer 1999 samples were collected at MT57B and all subsequent samples were collected at MT57. These sites were classified as filled.

Site MT60 was established on Left Fork downstream of both of the existing fills. These fills include the Hall Fork fill and a small fill in an unnamed tributary. Three additional fills are proposed for the headwaters of this stream. This site was classified as filled.

Site MT55 was established on Cow Creek below its confluence with Left Fork. This site also served as the cumulative downstream site for Cow Creek. There are four valley fills upstream of this site associated with mountaintop mining and one associated with the underground mine. There is also a small community located near the confluence of Cow Creek and Left Fork. The area disturbed by the surface mining in this watershed has different uses than the typical reclaimed area. There are residences, a log mill, small orchards and vineyards, beef cattle, and municipal sewage sludge disposal located on the surface mine. This site was classified as filled/residential.

Monitoring Site Attributes				
StationID	**EIS Class**	**Basin**	**Order**	**Watershed Area (acres)**
MT02	Unmined	Mud River	2	511
MT03	Unmined	Mud River	2	717
MT107	Unmined	Island Creek	1	382
MT13	Unmined	Mud River	1	335
MT39	Unmined	Spruce Fork	2	669
MT42	Unmined	Spruce Fork	1	447
MT50	Unmined	Island Creek	2	563
MT51	Unmined	Island Creek	2	1172
MT91	Unmined	Twentymile Creek	2	1302
MT95	Unmined	Twentymile Creek	2	968
MT103	Filled	Twentymile Creek	2	1027
MT104	Filled	Twentymile Creek	3	2455
MT14	Filled	Mud River	2	1527
MT15	Filled	Mud River	3	1114
MT18	Filled	Mud River	2	479
MT25B	Filled	Spruce Fork	2	997
MT32	Filled	Spruce Fork	3	2878
MT34B	Filled	Spruce Fork	3	1677
MT52	Filled	Island Creek	1	316
MT57	Filled	Island Creek	1	288
MT57B	Filled	Island Creek	1	125
MT60	Filled	Island Creek	2	790
MT64	Filled	Clear Fork	2	758
MT86	Filled	Twentymile Creek	3	2201
MT87	Filled	Twentymile Creek	2	752
MT98	Filled	Twentymile Creek	2	1208
MT23	Filled/Residences	Mud River	4	10618
MT40	Filled/Residences	Spruce Fork	4	11955
MT48	Filled/Residences	Spruce Fork	5	27742
MT55	Filled/Residences	Island Creek	3	3167
MT62	Filled/Residences	Clear Fork	3	3193
MT70	Filled/Residences	Clear Fork	2	1221
MT75	Filled/Residences	Clear Fork	3	876
MT106	Mined	Mud River	2	327

Monitoring Site Attributes				
StationID	**EIS Class**	**Basin**	**Order**	**Watershed Area (acres)**
MT45	Mined	Spruce Fork	3	1111
MT78	Mined	Clear Fork	2	524
MT79	Mined	Clear Fork	2	448
MT81	Mined	Clear Fork	3	1258
MT01	Mined/Residences	Mud River	3	1897
MT69	Mined/Residences	Clear Fork	2	708
MT24	Sediment Control Structure	Mud River	1	NA

Monitoring Site Attributes Continued		
StationID	StreamName	Location
MT02	Rushpatch Branch	approx. 500 ft. upstream of confluence with Mud River
MT03	Lukey Fork	approx 1 mile upstream of confluence with Mud River
MT107	Left Fork	approx. 100 m upstream of Hall Fork
MT13	Spring Branch of Ballard Fork	approx. 585 feet upstream of confluence with Ballard Fork
MT39	White Oak Branch	approx. 2000 ft. upstream of confluence with Spruce Fork
MT42	Oldhouse Branch	approx. 2400 ft upstream of confluence with Spruce Fork
MT50	Cabin Branch	approx. 650 ft upstream of confluence with Jack's Fork
MT51	Cabin Branch	approx. 1800 ft upstream of confluence with Copperas Mine Fork
MT91	Rader Fork	approx. 500 ft. upstream of confluence with Neff Fork
MT95	Neil Branch	approx. 500 ft. upstream of confluence with Twentymile Creek
MT103	Hughes Fork	approx. 2500 ft. upstream of confluence with Jim's Hollow
MT104	Hughes Fork	approx. 1.3 miles upstream of confluence with Bell's Fork. Downstream of pond on mainstem of Hughes Fork.
MT14	Ballard Fork	approx. 900 ft upstream of confluence with Mud River
MT15	Stanley Fork	approx. 700 ft upstream of confluence with Mud River
MT18	Sugartree Branch	approx. 2000 ft. upstream of confluence with Mud River
MT25B	Rockhouse Creek	approx. 1.2 miles upstream of confluence with Spruce Fork, downstream of pond
MT32	Beech Creek	approx 1.9 miles upstream of confluence with Spruce Fork
MT34B	Left Fork of Beech Creek	approx 900 ft upstream of confluence with Beech Creek, downstream of pond.
MT52	Cow Creek	approx 3 miles upstream of confluence with Left Fork
MT57	Hall Fork	approx. 500 ft upstream of Left Fork
MT57B	Hall Fork	approx. 3600 ft. upstream of Left Fork. Downstream of pond effluent
MT60	Left Fork	approx. 5000 ft. upstream of confluence with Cow Creek
MT64	Buffalo Fork	approx. 4900 ft. upstream of confluence with Toney Fork
MT86	Rader Fork	approx. 500 ft. upstream of confluence with Twentymile Creek
MT87	Neff Fork	approx. 800 ft. upstream of confluence with Rader Fork
MT98	Hughes Fork	approx. 200 ft. upstream of confluence with Jim's Hollow

Monitoring Site Attributes Continued		
StationID	**StreamName**	**Location**
MT23	Mud River	approx. 1300 ft. downstream of confluence with Connelly Branch, downstream of MTM
MT40	Spruce Fork	In Blair, directly upstream of confluence with White Trace Branch
MT48	Spruce Fork	approx 5100 ft downstream of confluence with Beech Creek
MT55	Cow Creek	approx. 1000 ft. downstream of confluence with Left Fork
MT62	Toney Fork	approx. 300 ft downstream of confluence with Buffalo Fork
MT70	Toney Fork	upstream of confluence with Ewing Fork
MT75	Toney Fork	approx 700 ft. downstream of Reeds Branch
MT106	NNT to Sugartree	upstream of confluence with Sugartree
MT45	Pigeonroost Branch	approx 4500 ft upstream of confluence with Spruce Fork
MT78	Raines Fork	approx. 400 ft. upstream of confluence with Sycamore Creek
MT79	Davis Fork	approx. 600 ft. upstream of confluence with Sycamore Creek
MT81	Sycamore Creek	approx. 500 ft. upstream of confluence with Lem Fork
MT01	Mud River	approx. 650 ft downstream of confluence with Rushpatch Branch
MT69	Ewing Fork	approx. 2000 ft. upstream of confluence withToney Fork
MT24	Stanley Fork	Stanley Fork Drainage, Sediment Control Structure

Monitoring Site Attributes Continued				
StationID	**Latitude**	**Longitude**	**USGS Quad**	**County**
MT02	38.050409	-81.932945	Mud	Boone
MT03	38.054968	-81.958674	Mud	Boone
MT107	37.710836	-82.037565	Barnabus	Logan
MT13	38.067288	-81.937647	Mud	Boone
MT39	37.862890	-81.803831	Amherstdale	Logan
MT42	37.873395	-81.822344	Amherstdale	Logan
MT50	37.844838	-82.103711	Holden	Logan
MT51	37.835209	-82.102368	Holden	Logan
MT91	38.344246	-80.958472	Gilboa	Nicholas
MT95	38.297422	-81.086116	Lockwood	Nicholas
MT103	38.249313	-81.258160	Mammoth	Kanawha
MT104	38.251236	-81.242886	Bentree	Kanawha
MT14	38.072155	-81.947080	Mud	Boone
MT15	38.084996	-81.956693	Mud	Boone
MT18	38.090552	-81.951047	Mud	Boone
MT25B	37.933609	-81.840678	Clothier	Logan
MT32	37.909185	-81.851805	Clothier	Logan
MT34B	37.905423	-81.846021	Clothier	Logan
MT52	37.709626	-82.064232	Barnabus	Logan
MT57	37.711111	-82.040286	Barnabus	Logan
MT57B	37.706352	-82.047282	Barnabus	Logan
MT60	37.715706	-82.040098	Barnabus	Logan
MT64	37.899344	-81.331196	Pax	Raleigh
MT86	38.352418	-80.958912	Gilboa	Nicholas
MT87	38.344591	-80.955857	Gilboa	Nicholas
MT98	38.250588	-81.251563	Mammoth	Kanawha
MT23	38.090968	-81.971783	Mud	Lincoln
MT40	37.874671	-81.832148	Clothier	Logan
MT48	37.932826	-81.823662	Clothier	Logan
MT55	37.726947	-82.029593	Barnabus	Logan
MT62	37.909472	-81.337667	Pax	Raleigh
MT70	37.910552	-81.325875	Pax	Raleigh
MT75	37.908626	-81.315588	Pax	Raleigh
MT106	38.094460	-81.951610	Mud	Boone
MT45	37.883155	-81.811142	Clothier	Logan

Monitoring Site Attributes Continued				
StationID	**Latitude**	**Longitude**	**USGS Quad**	**County**
MT78	37.919763	-81.407243	Dorothy	Raleigh
MT79	37.915166	-81.402750	Dorothy	Raleigh
MT81	37.907029	-81.403113	Dorothy	Raleigh
MT01	38.053931	-81.936138	Mud	Boone
MT69	37.913970	-81.324878	Pax	Raleigh
MT24	38.083213	-81.934656	Mud	Boone

APPENDIX 2. BENTHIC METRICS

Please contact the authors for electronic files of the taxonomic data**.**

Benthic Metrics - Spring 1999												
StationID	EIS CLass	CollDate	BenSamp ID	Tot Taxa	EPT %	Chiro %	EPT Tax	2Dom %	HBI	WV SCI R100	Ephem %	Ephem Tax
MT02	Unmined	04/19/99	04199902	25	40.71	47.27	13	56.83	4.97	70.40	19.67	5
MT03	Unmined	04/19/99	04199903	21	55.22	34.33	12	50.25	4.48	75.95	31.84	5
MT13	Unmined	04/20/99	04209901	21	70.15	19.39	13	38.01	3.15	86.27	31.89	5
MT39	Unmined	04/22/99	04229901	22	75.95	8.33	16	53.81	3.15	86.97	56.43	6
MT42	Unmined	04/22/99	04229907	21	80.92	9.25	13	29.48	3.46	94.88	38.73	5
MT50	Unmined	04/26/99	04269901	25	70.76	12.53	17	48.04	3.42	85.39	44.13	5
MT51	Unmined	04/26/99	04269902	16	84.86	6.25	11	57.93	2.99	81.35	45.67	5
MT91	Unmined	05/05/99	05059904	12	60.61	16.16	7	46.46	4.56	72.66	42.42	3
MT95	Unmined	05/05/99	05059905	22	65.59	30.00	17	44.71	4.36	84.28	26.18	5
MT14	Filled	04/20/99	04209902	13	53.04	36.82	6	80.07	4.37	54.92	4.73	2
MT15	Filled	04/20/99	04209903	9	22.02	63.30	4	77.98	5.89	39.15	0.00	0
MT18	Filled	04/20/99	04209908	10	32.46	25.22	3	59.42	5.19	50.09	0.00	0
MT25B	Filled	04/21/99	04219901	19	44.10	51.74	9	78.95	4.82	48.23	2.95	3
MT32	Filled	04/21/99	04219902	15	28.96	16.59	6	58.78	5.02	55.87	5.24	1
MT34B	Filled	04/21/99	04219903	13	57.61	26.63	4	77.72	4.27	56.43	0.00	0
MT52	Filled	04/26/99	04269903	20	67.35	7.22	11	47.77	3.96	81.84	25.09	4
MT57B	Filled	04/27/99	04279901	13	15.98	52.51	6	66.67	5.64	45.30	0.46	1
MT60	Filled	04/27/99	04279902	23	59.86	22.80	16	41.81	4.73	80.23	23.04	3
MT64	Filled	04/28/99	04289902	18	50.94	36.60	8	63.77	4.63	61.76	0.38	1
MT86	Filled	05/05/99	05059901	13	85.51	5.80	10	62.32	4.14	80.85	62.32	3
MT87	Filled	05/05/99	05059903	19	78.03	14.97	13	61.46	3.53	79.59	12.74	3
MT98	Filled	05/06/99	05069901	13	85.71	9.74	8	55.19	3.47	77.90	14.29	1
MT103	Filled	05/06/99	05069903	16	57.93	31.74	9	62.22	4.18	62.63	2.77	1
MT104	Filled	05/06/99	05069904	14	17.48	31.47	6	60.84	5.51	53.09	0.70	1
MT23	Filled/Residential	04/20/99	04209909	14	20.96	42.78	7	69.97	5.71	44.91	0.00	0
MT40	Filled/Residential	04/22/99	04229906	15	10.32	53.33	6	69.25	6.42	38.14	2.80	4
MT48	Filled/Residential	04/22/99	04229909	18	20.77	28.27	9	60.77	5.55	57.08	14.81	4
MT55	Filled/Residential	04/26/99	04269905	14	6.11	77.54	7	85.98	6.78	26.83	2.79	4
MT62	Filled/Residential	04/28/99	04289901	13	14.75	48.20	6	71.15	5.85	41.33	0.66	2
MT75	Filled/Residential	04/28/99	04289908	10	38.01	52.04	3	72.40	5.54	44.83	0.00	0
MT45	Mined	04/22/99	04229908	20	82.65	8.24	12	43.82	3.35	86.49	44.47	5
MT78	Mined	04/29/99	04299901	7	9.76	2.44	4	92.68	7.29	38.49	1.22	1
MT79	Mined	04/29/99	04299902	24	58.40	29.51	16	47.10	4.36	82.40	18.21	5
MT81	Mined	04/29/99	04299906	18	58.88	28.97	11	45.79	3.95	82.25	21.50	4
MT01	Mined/Residential	04/19/99	04199901	19	43.44	45.48	10	78.73	5.80	49.09	40.05	6

Benthic Metrics - Spring 1999												
StationID	**EIS CLass**	**CollDate**	**BenSamp ID**	**Tot Taxa**	**EPT %**	**Chiro %**	**EPT Tax**	**2Dom %**	**HBI**	**WV SCI R100**	**Ephem %**	**Ephem Tax**
MT69	Mined/Residential	04/28/99	04289903	16	46.80	36.70	10	63.30	4.66	62.61	2.89	2
MT24	Sediment Control Structure	04/20/99	04209910	9	1.07	75.73	1	83.20	6.96	23.48	0.00	0

Benthic Metrics - Summer 1999												
StationID	**EIS CLass**	**CollDate**	**BenSamp ID**	**Tot Taxa**	**EPT %**	**Chiro %**	**EPT Tax**	**2Dom %**	**HBI**	**WV SCI R100**	**Ephem %**	**Ephem Tax**
MT42	Unmined	7/29/99	07299912	16	48.26	5.81	9	37.79	4.28	78.59	19.77	3
MT91	Unmined	8/11/99	08119904	17	45.79	8.41	9	67.76	4.90	67.27	3.74	3.00
MT14	Filled	7/26/99	07269901	15	46.81	3.19	3	67.02	5.07	62.99	0.00	0
MT15	Filled	7/27/99	07279901	13	79.72	2.10	2	79.72	4.57	62.04	0.00	0
MT18	Filled	7/27/99	07279909	10	68.71	6.80	2	68.71	4.89	59.58	0.00	0
MT52	Filled	7/28/99	07289901	16	57.88	2.12	7	69.39	4.76	63.08	0.30	1
MT60	Filled	7/28/99	07289904	15	52.59	17.24	6	53.45	4.84	69.30	1.72	1
MT57B	Filled	7/28/99	07289905	18	29.85	23.13	6	44.78	5.08	65.91	0.75	1
MT34B	Filled	7/29/99	07299901	14	22.50	23.33	3	38.33	5.78	59.78	0.00	0
MT32	Filled	7/29/99	07299902	17	27.51	1.51	6	78.71	4.85	48.58	0.50	2
MT25B	Filled	7/29/99	07299903	15	66.10	20.34	6	81.60	5.48	54.72	0.00	0
MT64	Filled	8/10/99	08109909	13	56.92	9.88	5	69.57	4.61	60.70	0.00	0
MT86	Filled	8/11/99	08119901	11	60.19	25.93	4	70.37	4.89	58.45	0.00	0
MT87	Filled	8/11/99	08119903	13	77.23	11.88	5	82.18	4.97	64.16	0.00	0
MT98	Filled	8/12/99	08129901	10	68.82	9.41	5	68.82	4.86	61.98	2.35	1
MT103	Filled	8/12/99	08129903	11	56.35	24.31	6	53.04	3.99	65.77	1.10	1
MT104	Filled	8/12/99	08129904	12	33.33	37.76	4	68.37	5.84	46.82	0.68	1
MT23	Filled/Residential	7/27/99	07279910	13	33.12	27.27	5	56.49	5.15	57.90	0.00	0
MT48	Filled/Residential	7/27/99	07279912	16	51.41	11.44	6	72.01	4.66	59.38	1.94	3
MT40	Filled/Residential	7/27/99	07279914	14	28.29	40.44	6	64.54	5.86	48.92	4.78	3
MT55	Filled/Residential	7/28/99	07289902	12	21.89	17.60	4	59.66	5.54	52.76	3.86	3
MT62	Filled/Residential	8/10/99	08109901	15	18.89	39.56	4	73.22	5.74	41.02	0.11	1
MT75	Filled/Residential	8/10/99	08109911	11	30.88	50.53	3	80.00	5.94	40.13	0.00	0
MT45	Mined	7/29/99	07299911	19	62.91	5.09	8	42.18	3.95	80.77	21.09	3
MT79	Mined	8/9/99	08099901	18	65.29	14.12	9	62.35	4.67	70.41	0.00	0
MT69	Mined/Residential	8/10/99	08109910	15	61.86	8.47	4	67.37	5.20	61.73	0.00	0
MT24	Sediment Control Structure	7/27/99	07279911	12	1.52	82.68	3	89.39	6.98	21.57	0.43	1

Benthic Metrics - Fall 1999												
StationID	**EIS CLass**	**CollDate**	**BenSampID**	**Tot Tax**	**EPT %**	**Chiro %**	**EPT Tax**	**2Dom %**	**HBI**	**WV SCI R100**	**Ephem %**	**Ephem Tax**
MT91	Unmined	11/3/99	11039910	18	71.88	10.71	9	54.91	3.19	77.09	2.23	4
MT95	Unmined	11/3/99	11039911	4	18.18	0.00	2	90.91	6.67	36.64	0.00	0
MT18	Filled	10/25/99	10259902	17	35.65	35.22	5	55.22	5.19	58.37	0.00	0
MT15	Filled	10/26/99	10269901	12	64.08	12.68	4	50.70	3.53	70.28	0.00	0
MT14	Filled	10/26/99	10269909	7	88.11	7.49	3	83.26	1.87	62.56	0.00	0
MT25B	Filled	10/27/99	10279902	15	56.93	33.58	8	54.01	4.47	69.45	0.00	0
MT32	Filled	10/27/99	10279910	14	47.50	10.19	5	60.79	4.46	58.29	0.00	0
MT60	Filled	10/28/99	10289901	17	85.04	8.76	9	72.63	2.70	74.99	1.46	2
MT57	Filled	10/28/99	10289902	15	89.20	4.23	8	84.74	1.85	69.44	0.23	1
MT52	Filled	10/28/99	10289904	16	84.14	2.76	10	79.08	2.02	70.99	0.92	2
MT64	Filled	11/2/99	11029903	17	67.11	23.54	10	67.88	4.64	63.05	0.11	1
MT86	Filled	11/3/99	11039901	11	72.73	12.50	7	53.41	2.90	76.62	3.41	1
MT87	Filled	11/3/99	11039902	11	86.57	7.46	7	59.70	2.34	78.34	2.99	1
MT98	Filled	11/4/99	11049901	12	91.93	4.91	7	67.37	2.52	72.94	1.40	2
MT103	Filled	11/4/99	11049902	14	83.33	11.98	8	57.81	3.29	74.02	1.30	2
MT104	Filled	11/4/99	11049903	11	58.58	7.10	4	59.76	4.26	64.35	0.00	0
MT23	Filled/Resid ential	10/25/99	10259901	13	63.43	9.72	6	51.85	4.61	68.01	0.23	1
MT40	Filled/Resid ential	10/27/99	10279911	16	25.35	49.30	9	63.38	5.74	52.75	2.35	4
MT55	Filled/Resid ential	10/28/99	10289903	11	12.50	60.29	4	80.64	6.20	34.20	0.49	1
MT48	Filled/Resid ential	10/29/99	10299901	19	42.73	31.63	10	52.83	4.82	62.94	4.11	3
MT62	Filled/Resid ential	11/2/99	11029901	17	49.64	16.61	6	52.08	4.32	61.42	0.27	2
MT70	Filled/Resid ential	11/2/99	11029906	13	76.32	15.13	4	84.87	2.51	61.11	0.33	1
MT45	Mined	10/27/99	10279901	20	83.04	3.12	11	53.57	2.85	88.75	7.14	4
MT01	Mined/Resi dential	10/26/99	10269910	10	12.93	70.26	4	79.74	6.06	33.60	0.86	2
MT69	Mined/Resi dential	11/2/99	11029905	13	92.13	2.30	7	76.39	2.20	70.18	0.00	0
MT24	Sediment Control Structure	10/26/99	10269911	9	0.00	65.21	0	87.87	6.80	22.23	0.00	0

Benthic Metrics - Winter 2000												
StationID	**EIS CLass**	**CollDate**	**BenSamp ID**	**Tot Tax**	**EPT %**	**Chiro %**	**EPT Tax**	**2Dom %**	**HB I**	**WV SCI R100**	**Ephem %**	**Ephem Tax**
MT13	Unmined	1/25/00	01250010	15	81.82	4.55	10	38.64	2.07	91.33	40.91	3
MT03	Unmined	1/25/00	01250011	19	84.52	5.36	13	31.55	2.57	96.45	41.07	5
MT02	Unmined	1/25/00	01250018	23	58.64	24.07	14	41.36	3.67	86.87	27.16	5
MT42	Unmined	1/26/00	01260002	26	68.63	18.30	17	28.43	3.50	91.45	30.72	4
MT39	Unmined	1/26/00	01260003	18	55.21	32.42	10	57.76	4.29	67.80	12.97	4
MT51	Unmined	1/27/00	01270004	13	87.20	3.66	8	69.51	2.80	78.56	8.54	4
MT50	Unmined	1/31/00	01310001	21	81.46	11.92	14	36.42	3.02	95.87	28.48	4
MT91	Unmined	2/7/00	02070010	17	89.86	4.93	10	78.36	2.71	77.62	15.89	4
MT95	Unmined	2/8/00	02080005	19	67.57	15.32	13	30.63	4.06	90.44	30.63	4
MT18	Filled	1/24/00	01240002	13	9.88	56.89	3	85.03	6.39	32.14	0.00	0
MT15	Filled	1/25/00	01250001	8	12.22	63.33	4	81.11	6.32	34.90	0.00	0
MT14	Filled	1/25/00	01250009	12	61.54	21.15	4	44.23	3.92	69.89	0	0
MT25B	Filled	1/26/00	01260010	19	47.55	50.38	12	81.32	4.67	50.56	0.75	2
MT32	Filled	1/26/00	01260017	17	28.10	40.70	7	63.21	5.44	48.66	0.00	0
MT52	Filled	1/27/00	01270006	20	77.57	15.01	13	45.34	2.92	86.36	15.32	4
MT60	Filled	1/31/00	01310002	18	77.19	17.54	13	32.46	3.62	92.12	11.40	3
MT57	Filled	1/31/00	01310004	16	52.10	43.70	11	72.27	4.56	66.93	5.88	3
MT64	Filled	2/1/00	02010009	17	32.63	62.11	11	71.58	5.50	52.84	0.70	1
MT86	Filled	2/7/00	02070001	22	69.72	25.08	14	62.08	3.87	73.58	18.96	4
MT87	Filled	2/7/00	02070003	20	82.24	15.35	13	58.77	3.54	78.46	39.04	4
MT103	Filled	2/8/00	02080001	13	54.59	41.74	7	68.81	4.10	60.63	1.38	1
MT98	Filled	2/8/00	02080002	16	63.83	29.79	10	51.60	3.92	72.72	2.13	3
MT104	Filled	2/8/00	02080004	16	35.61	37.12	7	66.67	5.70	56.83	1.52	2
MT23	Filled/Residential	1/24/00	01240001	16	30.00	45.13	7	58.72	5.68	53.02	0.26	1
MT48	Filled/Residential	1/27/00	01270001	17	8.18	72.12	8	81.41	6.23	35.06	1.86	2
MT40	Filled/Residential	1/27/00	01270003	14	4.59	65.65	6	86.05	6.84	28.97	1.02	3
MT55	Filled/Residential	1/27/00	01270005	9	10.29	79.78	3	89.52	6.60	23.22	0.00	0
MT62	Filled/Residential	2/1/00	02010017	9	11.84	78.68	5	87.14	6.41	28.25	0.00	0
MT70	Filled/Residential	2/2/00	02020003	15	38.12	55.48	9	84.31	5.08	42.40	0.00	0
MT45	Mined	1/26/00	01260001	21	76.47	9.56	12	27.21	3.15	94.15	36.03	4
MT79	Mined	2/1/00	02010001	20	68.69	27.27	15	46.46	3.86	81.10	12.79	4

Benthic Metrics - Winter 2000												
StationID	**EIS CLass**	**CollDate**	**BenSamp ID**	**Tot Tax**	**EPT %**	**Chiro %**	**EPT Tax**	**2Dom %**	**HB I**	**WV SCI R100**	**Ephem %**	**Ephem Tax**
MT81	Mined	2/1/00	02010002	23	67.52	30.74	16	51.68	3.75	81.35	32.62	4
MT01	Mined/Residential	1/24/00	01240003	9	9.68	38.71	3	58.06	5.94	45.03	6.45	2
MT69	Mined/Residential	2/2/00	02020001	16	84.63	11.07	8	77.87	2.73	68.34	0.20	1
MT24	Sediment Cont. Struct.	1/25/00	01250019	13	0.14	89.07	1	93.75	6.96	16.17	0.14	1

Benthic Metrics - Spring 2000												
StationID	**EIS CLass**	**CollDate**	**BenSamp ID**	**Tot Taxa**	**EPT %**	**Chiro %**	**EPT Tax**	**2Dom %**	**HBI**	**WV SCI R100**	**Ephem %**	**Ephem Tax**
MT02	Unmined	04/17/00	04170001	19	59.72	23.61	11	40.28	4.01	85.24	19.44	4
MT03	Unmined	04/18/00	04180001	22	69.57	9.94	14	32.92	3.47	93.10	32.30	6
MT13	Unmined	04/18/00	04180010	20	69.28	7.19	12	38.56	3.73	90.35	44.44	5
MT51	Unmined	04/24/00	04240001	12	76.92	15.38	8	46.15	3.44	79.85	30.77	4
MT50	Unmined	04/24/00	04240002	15	76.25	12.50	9	37.50	3.52	86.42	46.25	5
MT39	Unmined	04/25/00	04250007	20	64.88	9.52	13	36.90	3.51	90.25	40.48	6
MT42	Unmined	04/25/00	04250008	20	68.10	18.10	13	35.34	4.02	90.18	38.79	4
MT107	Unmined	04/26/00	04260004	13	87.63	10.22	10	59.68	2.75	80.48	24.73	3
MT95	Unmined	05/03/00	05030005	18	58.25	29.13	12	44.66	4.59	82.54	24.27	4
MT91	Unmined	05/04/00	05040010	20	87.38	5.83	14	52.10	3.56	84.64	45.31	4
MT14	Filled	04/18/00	04180009	6	19.15	76.60	4	87.23	6.13	30.94	2.13	1
MT15	Filled	04/18/00	04180011	5	3.30	57.10	2	96.04	6.45	22.57	0.00	0
MT18	Filled	04/18/00	04180018	12	2.00	34.91	4	93.77	6.29	29.31	0.25	1
MT34B	Filled	04/25/00	04250010	11	7.20	12.49	3	88.47	5.88	37.60	0.00	0
MT25B	Filled	04/25/00	04250011	14	52.00	44.51	9	72.46	4.96	51.56	17.80	2
MT60	Filled	04/26/00	04260001	15	75.00	6.90	8	62.07	3.78	77.81	29.31	2
MT57	Filled	04/26/00	04260003	16	66.67	23.81	9	62.70	3.83	74.39	12.70	1
MT52	Filled	04/26/00	04260005	15	70.41	6.12	10	30.61	3.66	87.89	33.67	5
MT32	Filled	04/27/00	04270001	16	17.51	38.28	9	64.27	5.38	48.62	1.27	2
MT64	Filled	05/02/00	05020003	14	23.29	70.50	7	81.68	5.82	40.01	0.00	0
MT98	Filled	05/03/00	05030001	16	65.14	28.13	11	50.15	3.73	73.10	11.31	1
MT103	Filled	05/03/00	05030003	14	69.25	24.87	10	45.72	3.40	75.35	5.08	1
MT104	Filled	05/03/00	05030004	13	29.79	61.28	5	76.60	5.61	44.59	4.26	1
MT86	Filled	05/04/00	05040001	18	83.45	14.79	13	62.32	3.84	76.56	39.08	3
MT87	Filled	05/04/00	05040003	17	84.70	10.38	11	48.09	3.27	87.55	21.31	2
MT23	Filled/Residential	04/19/00	04190001	13	14.48	69.66	8	76.55	6.25	42.33	2.76	3
MT55	Filled/Residential	04/26/00	04260006	13	26.14	70.02	9	79.38	6.11	40.05	7.67	4
MT62	Filled/Residential	05/02/00	05020001	15	29.07	55.91	8	69.33	5.59	48.38	6.39	1
MT70	Filled/Residential	05/02/00	05020002	10	17.41	77.41	6	86.67	6.14	34.05	2.59	1
MT48	Filled/Residential	05/10/00	05100001	11	7.88	53.33	5	83.64	6.86	35.19	3.64	1
MT40	Filled/Residential	05/10/00	05100002	14	23.49	37.48	8	72.02	6.70	43.38	17.27	3
MT106	Mined	04/18/00	04180019	17	71.59	17.05	10	56.82	3.64	82.76	5.68	3
MT45	Mined	04/25/00	04250009	17	54.17	20.83	10	33.33	4.40	82.58	29.17	4
MT78	Mined	05/01/00	05010001	9	26.11	71.34	7	85.35	6.06	39.45	18.47	3

Benthic Metrics - Spring 2000												
StationID	**EIS CLass**	**CollDate**	**BenSamp ID**	**Tot Taxa**	**EPT %**	**Chiro %**	**EPT Tax**	**2Dom %**	**HBI**	**WV SCI R100**	**Ephem %**	**Ephem Tax**
MT79	Mined	05/01/00	05010002	17	65.28	31.94	13	52.78	4.07	80.07	8.33	3
MT81	Mined	05/01/00	05010003	21	54.17	39.35	14	54.17	4.65	77.00	35.19	5.00
MT01	Mined/Residential	04/17/00	04170002	11	15.79	73.03	6	81.58	6.35	37.10	12.5	4.00
MT69	Mined/Residential	05/02/00	05020005	16	43.71	39.94	9	68.87	4.77	59.34	2.52	1
MT24	Sediment Cont. Struct.	04/19/00	04190003	11	1.49	60.89	2	91.97	6.67	24.41	1.15	1

APPENDIX 3. FIELD CHEMICAL/PHYSICAL, PHYSICAL HABITAT AND SUBSTRATE SIZE DATA

Field Chemistry - Spring 1999						
StationID	**Basin**	**EIS Class**	**Collection Date**	**Conductivity (uS/cm)**	**pH (su)**	**Temperature ©**
MT02	Mud River	Unmined	4/19/99	60	6.76	14.7
MT03	Mud River	Unmined	4/19/99	49	6.80	15.5
MT13	Mud River	Unmined	4/20/99	51	7.73	9.8
MT39	Spruce Fork	Unmined	4/22/99	103	8.17	12.5
MT42	Spruce Fork	Unmined	4/22/99	74	8.29	16.5
MT50	Island Creek	Unmined	4/26/99	55	8.21	12.5
MT51	Island Creek	Unmined	4/26/99	71	8.02	13.8
MT91	Twentymile Creek	Unmined	5/5/99	73	6.57	13.3
MT95	Twentymile Creek	Unmined	5/5/99	38	6.91	13.1
MT103	Twentymile Creek	Filled	5/6/99	937	7.60	12.6
MT104	Twentymile Creek	Filled	5/6/99	731	7.95	14.2
MT14	Mud River	Filled	4/20/99	1201	8.10	11.8
MT15	Mud River	Filled	4/20/99	1970	8.33	14.6
MT18	Mud River	Filled	4/20/99	1854	8.20	14.8
MT25B	Spruce Fork	Filled	4/21/99	861	8.14	10.4
MT32	Spruce Fork	Filled	4/21/99	741	8.36	13.0
MT34B	Spruce Fork	Filled	4/21/99	2160	8.16	15.3
MT52	Island Creek	Filled	4/26/99	256	8.16	11.9
MT57B	Island Creek	Filled	4/27/99	669	8.43	14.1
MT60	Island Creek	Filled	4/27/99	303	8.45	14.0
MT64	Clear Fork	Filled	4/28/99	984	8.37	12.3
MT86	Twentymile Creek	Filled	5/5/99	233	6.82	11.2
MT87	Twentymile Creek	Filled	5/5/99	409	6.27	13.2
MT98	Twentymile Creek	Filled	5/6/99	873	7.47	12.6
MT23	Mud River	Filled & Residences	4/20/99	927	8.47	15.3
MT40	Spruce Fork	Filled & Residences	4/22/99	505	7.85	16.0
MT48	Spruce Fork	Filled & Residences	4/22/99	633	8.05	19.3
MT55	Island Creek	Filled & Residences	4/26/99	276	8.04	13.5
MT62	Clear Fork	Filled & Residences	4/28/99	734	8.53	12.1
MT75	Clear Fork	Filled & Residences	4/28/99	836	8.60	11.6
MT45	Spruce Fork	Mined	4/22/99	187	7.96	19.4
MT78	Clear Fork	Mined	4/29/99	118	8.65	8.9
MT79	Clear Fork	Mined	4/29/99	293	8.62	9.8
MT81	Clear Fork	Mined	4/29/99	90	8.51	9.2
MT01	Mud River	Mined & Residences	4/19/99	115	6.70	14.7
MT69	Clear Fork	Mined & Residences	4/28/99	729	8.54	12.0
MT24	Mud River	Sediment Control Structure	4/20/99	2510	8.36	15.1

Field Chemistry - Summer 1999							
StationID	Basin	EIS CLass	Collection Date	Conductivity (uS/cm)	DO (mg/L)	pH (su)	Temperature ©
MT42	Spruce Fork	Unmined	7/29/99	101	7.3	7.01	24.0
MT91	Twentymile Creek	Unmined	8/11/99	178	5.6	7.50	22.7
MT103	Twentymile Creek	Filled	8/12/99	1054	8.5	7.88	15.8
MT104	Twentymile Creek	Filled	8/12/99	892	8.3	8.15	22.5
MT14	Mud River	Filled	7/26/99	2300	7.0	8.22	25.4
MT15	Mud River	Filled	7/27/99	2500	7.9	7.94	22.8
MT18	Mud River	Filled	7/27/99	2270	7.7	7.64	23.7
MT25B	Spruce Fork	Filled	7/29/99	890	5.8	7.05	21.7
MT32	Spruce Fork	Filled	7/29/99	1178	6.7	8.11	22.8
MT34B	Spruce Fork	Filled	7/29/99	1461	5.9	7.43	23.5
MT52	Island Creek	Filled	7/28/99	850	7.0	7.74	21.5
MT57B	Island Creek	Filled	7/28/99	1293	6.5	7.65	23.8
MT60	Island Creek	Filled	7/28/99	595	6.8	7.88	20.9
MT64	Clear Fork	Filled	8/10/99	1148	9.1	7.97	16.6
MT86	Twentymile Creek	Filled	8/11/99	489	8.5	6.95	18.3
MT87	Twentymile Creek	Filled	8/11/99	530	8.0	7.27	19.2
MT98	Twentymile Creek	Filled	8/12/99	1025	8.4	8.09	16.3
MT23	Mud River	Filled & Residences	7/27/99	1532	7.3	7.95	26.1
MT40	Spruce Fork	Filled & Residences	7/27/99	1023	9.1	8.66	26.3
MT48	Spruce Fork	Filled & Residences	7/27/99	1067	8.7	8.44	25.0
MT55	Island Creek	Filled & Residences	7/28/99	688	7.4	8.13	21.5
MT62	Clear Fork	Filled & Residences	8/10/99	1141	9.8	8.17	15.3
MT75	Clear Fork	Filled & Residences	8/10/99	1292	8.6	8.31	19.0
MT45	Spruce Fork	Mined	7/29/99	264	8.7	7.42	21.9
MT79	Clear Fork	Mined	8/9/99	618	9.9	6.85	18.4
MT81	Clear Fork	Mined	8/9/99	274	7.4	7.08	18.2
MT69	Clear Fork	Mined & Residences	8/10/99	1165	8.5	7.84	17.5
MT24	Mud River	Sediment Control Structure	7/27/99	3490	3.6	7.51	26.9

Field Chemistry - Fall 1999							
StationID	**Basin**	**EIS CLass**	**Collection Date**	**Conductivity (uS/cm)**	**DO (mg/L)**	**pH (su)**	**Temperature ©**
MT91	Twentymile Creek	Unmined	11/3/99	133	11.7	7.36	8.5
MT95	Twentymile Creek	Unmined	11/3/99	49	11.3	7.65	9.1
MT103	Twentymile Creek	Filled	11/4/99	1060	11.4	7.00	4.8
MT104	Twentymile Creek	Filled	11/4/99	940	11.4	7.75	8.3
MT14	Mud River	Filled	10/26/99	1437	9.6	7.44	7.7
MT15	Mud River	Filled	10/26/99	1764	10.3	7.78	7.1
MT18	Mud River	Filled	10/25/99	1565	9.3	7.30	10.7
MT25B	Spruce Fork	Filled	10/27/99	785	8.4	7.60	11.1
MT32	Spruce Fork	Filled	10/27/99	1000	10.7	8.22	9.3
MT52	Island Creek	Filled	10/28/99	774	8.1	7.91	11.9
MT57	Island Creek	Filled	10/28/99	618	9.8	7.00	8.5
MT60	Island Creek	Filled	10/28/99	537	10.1	7.00	7.2
MT64	Clear Fork	Filled	11/2/99	1226	9.4	7.64	13.9
MT86	Twentymile Creek	Filled	11/2/99	304	11.6	7.13	8.4
MT87	Twentymile Creek	Filled	11/3/99	420	11.8	6.79	7.9
MT98	Twentymile Creek	Filled	11/4/99	986	11.8	7.53	4.8
MT23	Mud River	Filled & Residences	10/25/99	1087	9.3	7.16	10.5
MT40	Spruce Fork	Filled & Residences	10/27/99	826	9.8		15.1
MT48	Spruce Fork	Filled & Residences	10/29/99	1000	10.4	7.63	8.0
MT55	Island Creek	Filled & Residences	10/28/99	629	10.6	7.38	8.0
MT62	Clear Fork	Filled & Residences	11/2/99	1223	9.0	7.37	13.7
MT70	Clear Fork	Filled & Residences	11/2/99	1141	9.5	8.06	15.0
MT45	Spruce Fork	Mined	10/27/99	260	10.4	6.73	6.3
MT01	Mud River	Mined & Residences	10/26/99	277	9.0	8.13	12.1
MT69	Clear Fork	Mined & Residences	11/2/99	1247	8.9	8.03	15.8
MT24	Mud River	Sediment Control Structure	10/26/99	2140	9.0	7.99	9.8

Field Chemistry - Winter 2000							
StationID	**Basin**	**EIS CLass**	**Collection Date**	**Conductivity (uS/cm)**	**DO (mg/L)**	**pH (su)**	**Temperature ©**
MT02	Mud River	Unmined	1/25/00	66	13.3	7.51	0.9
MT03	Mud River	Unmined	1/25/00	57	13.3	7.78	0.9
MT13	Mud River	Unmined	1/25/00	58	13.1	9.35	0.4
MT39	Spruce Fork	Unmined	1/26/00	104	13.4	7.43	1.3
MT42	Spruce Fork	Unmined	1/26/00	77	13.1	6.47	1.7
MT50	Island Creek	Unmined	1/31/00	50	13.0	7.72	0.7
MT51	Island Creek	Unmined	1/27/00	72	15.2	6.33	0.4
MT91	Twentymile Creek	Unmined	2/7/00	132	12.1	8.40	5.0
MT95	Twentymile Creek	Unmined	2/8/00	40	13.3	7.92	3.0
MT103	Twentymile Creek	Filled	2/8/00	808	12.7	7.54	4.9
MT104	Twentymile Creek	Filled	2/8/00	689	13.1	8.43	3.7
MT14	Mud River	Filled	1/25/00	1050	14.0	7.89	0.9
MT15	Mud River	Filled	1/25/00	1740		7.27	-0.1
MT18	Mud River	Filled	1/24/00	1674	11.7	7.58	5.2
MT25B	Spruce Fork	Filled	1/26/00	827	13.8	7.83	5.2
MT32	Spruce Fork	Filled	1/26/00	762	14.5	8.33	2.0
MT52	Island Creek	Filled	1/27/00	585	14.1	7.40	1.4
MT57	Island Creek	Filled	1/31/00	504	12.0	7.94	3.2
MT60	Island Creek	Filled	1/31/00	434	12.5	7.92	2.5
MT64	Clear Fork	Filled	2/1/00	1016	12.4	7.72	1.4
MT86	Twentymile Creek	Filled	2/7/00	296	13.0	7.15	3.9
MT87	Twentymile Creek	Filled	2/7/00	535	12.4	7.37	3.0
MT98	Twentymile Creek	Filled	2/8/00	787	12.9	8.30	3.5
MT23	Mud River	Filled & Residences	1/24/00	940	13.0	7.68	2.6
MT40	Spruce Fork	Filled & Residences	1/27/00	727	15.1	8.51	2.4
MT48	Spruce Fork	Filled & Residences	1/27/00	859	14.1	7.89	1.8
MT55	Island Creek	Filled & Residences	1/27/00	573	16.1	6.98	0.4
MT62	Clear Fork	Filled & Residences	2/1/00	899	12.0	8.08	1.5
MT70	Clear Fork	Filled & Residences	2/2/00	1066	13.8		0.8
MT45	Spruce Fork	Mined	1/26/00	186	14.5	6.41	0.5
MT79	Clear Fork	Mined	2/1/00	449	12.3	7.60	1.8
MT81	Clear Fork	Mined	2/1/00	128	11.4	7.91	4.3
MT01	Mud River	Mined & Residences	1/24/00	258	13.8	8.12	0.8
MT69	Clear Fork	Mined & Residences	2/2/00	907	14.6	7.46	0.7
MT24	Mud River	Sediment Control Structure	1/25/00	2110	13.3	7.69	2.4

Field Chemistry - Spring 2000							
StationID	**Basin**	**EIS CLass**	**Collection Date**	**Conductivity (uS/cm)**	**DO (mg/L)**	**pH (su)**	**Temperature ©**
MT02	Mud River	Unmined	4/17/00	47	8.2	5.68	14.4
MT03	Mud River	Unmined	4/18/00	42	10.5	7.10	10.6
MT107	Island Creek	Unmined	4/26/00	133	8.1	7.47	12.0
MT13	Mud River	Unmined	4/18/00	44	10.0	7.50	10.1
MT39	Spruce Fork	Unmined	4/25/00	64	10.1	6.75	11.1
MT42	Spruce Fork	Unmined	4/25/00	47	10.9	7.25	10.5
MT50	Island Creek	Unmined	4/24/00	45	9.2	7.62	11.8
MT51	Island Creek	Unmined	4/24/00	56	9.1	7.82	11.5
MT91	Twentymile Creek	Unmined	5/4/00	67	8.9	6.38	14.2
MT95	Twentymile Creek	Unmined	5/3/00	39	9.5	7.49	15.2
MT103	Twentymile Creek	Filled	5/3/00	850	10.5	7.39	11.1
MT104	Twentymile Creek	Filled	5/3/00	650	10.6	7.90	13.7
MT14	Mud River	Filled	4/18/00	464	9.6	7.05	11.5
MT15	Mud River	Filled	4/18/00	1387	10.3	7.96	11.0
MT18	Mud River	Filled	4/18/00	976	10.0	7.69	13.3
MT25B	Spruce Fork	Filled	4/25/00	575	10.0	8.12	13.2
MT32	Spruce Fork	Filled	4/27/00	454	10.7	6.25	9.7
MT34B	Spruce Fork	Filled	4/25/00	1210	7.4	6.89	15.5
MT52	Island Creek	Filled	4/26/00	159	10.9	6.80	12.3
MT57	Island Creek	Filled	4/26/00	236	9.6	7.00	8.6
MT60	Island Creek	Filled	4/26/00	212	10.2	5.94	8.6
MT64	Clear Fork	Filled	5/2/00	1011	9.2	7.77	14.5
MT86	Twentymile Creek	Filled	5/4/00	242	9.1	6.04	13.3
MT87	Twentymile Creek	Filled	5/4/00	441	9.4	5.95	14.0
MT98	Twentymile Creek	Filled	5/3/00	773	10.7	7.85	10.6
MT23	Mud River	Filled & Residences	4/19/00	426	9.2	6.70	11.8
MT40	Spruce Fork	Filled & Residences	5/10/00	460	8.8	8.02	18.1
MT48	Spruce Fork	Filled & Residences	5/10/00	589	8.9	7.47	17.5
MT55	Island Creek	Filled & Residences	4/26/00	155	9.0	6.40	16.5
MT62	Clear Fork	Filled & Residences	5/2/00	751	9.4	6.97	13.0
MT70	Clear Fork	Filled & Residences	5/2/00	849	9.4	7.30	13.5
MT106	Mud River	Mined	4/18/00	152	10.5	8.54	10.5
MT45	Spruce Fork	Mined	4/25/00	94	10.7	7.39	10.8
MT78	Clear Fork	Mined	5/1/00	108	9.5	6.03	12.8
MT79	Clear Fork	Mined	5/1/00	466	9.4	6.26	14.6
MT81	Clear Fork	Mined	5/1/00	138	9.3	6.50	14.1
MT01	Mud River	Mined & Residences	4/17/00	76	8.0	6.36	16.7
MT69	Clear Fork	Mined & Residences	5/2/00	742	9.9	7.83	14.6

Field Chemistry - Spring 2000							
StationID	Basin	EIS CLass	Collection Date	Conductivity (uS/cm)	DO (mg/L)	pH (su)	Temperature ©
MT24	Mud River	Sediment Control Structure	4/19/00	1980	6.6	7.13	13.9

Rapid Habitat Assessment Data - Spring 2000																
StationID	EIS CLass	Coll Date	Bank Sta-LB	Bank Sta-RB	Bank Veg P-LB	Bank Veg P-RB	Channel FlowS	Chan Alter	Embed-dedness	EpiFau Substrate	FreqOf Riffles	RipVeg ZW-LB	RipVeg ZW-RB	Sed Dep	Vel Depth	TotHab Score
MT02	Unmined	4/17/00	5	7	8	6	18	17	14	16	18	3	9	11	17	149
MT03	Unmined	4/18/00	8	9	8	8	18	18	13	11	18	9	9	14	10	153
MT107	Unmined	4/26/00	8	9	6	9	17	16	15	12	16	7	10	14	10	149
MT13	Unmined	4/18/00	9	9	9	8	18	18	16	16	18	9	9	14	10	163
MT39	Unmined	4/25/00	8	5	9	8	17	17	16	19	20	8	7	17	10	161
MT42	Unmined	4/25/00	8	9	7	9	17	16	16	19	19	7	9	15	14	165
MT50	Unmined	4/24/00	6	5	8	6	17	16	11	16	17	8	6	10	16	142
MT51	Unmined	4/24/00	7	4	8	2	19	15	12	18	18	8	1	13	16	141
MT91	Unmined	5/4/00	8	8	9	5	16	17	16	18	17	9	6	15	15	159
MT95	Unmined	5/3/00	6	7	9	9	18	17	19	18	18	10	8	19	10	168
MT103	Filled	5/3/00	9	7	7	4	17	18	14	16	18	7	7	13	10	147
MT104	Filled	5/3/00	9	8	8	8	17	15	17	11	16	9	9	13	10	150
MT14	Filled	4/18/00	6	8	9	7	18	17	12	14	17	9	7	8	16	148
MT15	Filled	4/18/00	8	8	7	9	18	15	14	11	17	9	7	6	16	145
MT18	Filled	4/18/00	8	5	9	4	18	13	12	17	17	9	3	10	13	138
MT25B	Filled	4/25/00	5	4	6	8	19	15	16	18	19	6	9	13	14	152
MT32	Filled	4/27/00	8	8	4	8	20	7	13	14	16	2	6	10	17	133
MT34B	Filled	4/25/00	8	9	6	9	18	10	9	11	16	4	9	7	10	126
MT52	Filled	4/26/00	8	5	9	5	18	12	12	17	18	9	4	13	16	146
MT57	Filled	4/26/00	8	9	9	9	19	16	12	17	18	9	9	10	10	155
MT60	Filled	4/25/00	8	9	7	9	17	16	16	17	19	6	9	14	10	157
MT64	Filled	5/2/00	8	5	5	7	17	18	16	18	18	3	6	16	10	147
MT86	Filled	5/4/00	9	7	10	7	16	18	17	19	18	10	6	16	17	170
MT87	Filled	5/4/00	7	6	7	9	18	14	17	17	17	6	9	17	10	154
MT98	Filled	5/3/00	9	9	8	8	18	16	18	17	18	9	2	17	10	159
MT23	Filled & Residences	4/19/00	8	7	6	4	18	14	14	12	16	3	2	5	16	125

Rapid Habitat Assessment Data - Spring 2000																
StationID	EIS CLass	Coll Date	Bank Sta-LB	Bank Sta-RB	Bank Veg P-LB	Bank Veg P-RB	Channel FlowS	Chan Alter	Embed-dedness	EpiFau Substrate	FreqOf Riffles	RipVeg ZW-LB	RipVeg ZW-RB	Sed Dep	Vel Depth	TotHab Score
MT40	Filled & Residences	5/10/00	6	9	4	9	17	12	14	14	18	1	9	14	17	144
MT48	Filled & Residences	5/10/00	8	8	9	9	16	15	14	18	18	8	7	12	18	160
MT55	Filled & Residences	4/26/00	6	9	3	8	20	10	15	8	17	2	8	17	15	138
MT62	Filled & Residences	5/2/00	9	9	9	3	17	12	15	17	17	9	1	15	14	147
MT70	Filled & Residences	5/2/00	6	6	8	8	19	17	12	12	17	7	9	13	16	150
MT106	Mined	4/18/00	8	8	6	7	17	17	16	16	18	9	6	10	10	148
MT45	Mined	4/25/00	8	8	9	6	18	13	17	18	17	9	5	15	16	159
MT78	Mined	5/1/00	9	9	9	9	13	18	18	18	18	9	10	18	10	168
MT79	Mined	5/1/00	9	8	9	8	15	16	15	19	19	9	8	16	10	161
MT81	Mined	5/1/00	8	8	8	7	15	16	15	19	19	8	8	17	10	158
MT01	Mined & Residences	4/17/00	9	7	8	6	18	14	15	11	16	8	6	14	10	142
MT69	Mined & Residences	5/2/00	8	9	9	9	16	19	15	16	18	9	9	14	10	161
MT24	Sediment Control Structure	4/19/00	9	9	8	8	18	0		5	16	2	1		10	86

Substrate Size Characterization Data - Spring 2000				
Station ID	**EIS Class**	**Mean Size Class**	**Estimated Geometric Mean Diameter (mm)**	**% sand and fines (% < or = to 2mm)**
MT02	Unmined	3.41	31.1	27.3
MT03	Unmined	4.13	152.0	16.4
MT107	Unmined	3.91	93.9	12.7
MT13	Unmined	3.33	25.9	20.0
MT39	Unmined	3.96	105.9	5.5
MT42	Unmined	3.47	35.8	16.4
MT50	Unmined	3.7	59.1	16.4
MT51	Unmined	3.18	18.8	36.4
MT91	Unmined	3.55	42.0	16.4
MT95	Unmined	3.81	75.3	1.8
MT103	Filled	3.47	35.8	21.8
MT104	Filled	4.50	346.4	14.6
MT14	Filled	3.09	15.4	32.7
MT15	Filled	2.97	11.9	34.6
MT18	Filled	3.52	39.6	16.4
MT25B	Filled	3.91	93.9	1.8
MT32	Filled	2.70	6.5	47.3
MT34B	Filled	3.05	14.2	30.9
MT52	Filled	3.42	31.7	25.5
MT57	Filled	3.29	23.9	32.7
MT60	Filled	3.61	48.4	18.2
MT64	Filled	3.78	70.8	9.1
MT86	Filled	3.54	41.2	7.3
MT87	Filled	3.75	65.4	10.9
MT98	Filled	3.91	93.9	7.3
MT23	Filled & Residences	2.34	2.7	78.2
MT40	Filled & Residences	3.68	56.8	14.6
MT48	Filled & Residences	3.25	22.1	25.5
MT55	Filled & Residences	4.80	672.3	16.4
MT62	Filled & Residences	4.04	124.3	20.0
MT70	Filled & Residences	3.17	18.3	23.6
MT106	Mined	3.75	66.7	9.1
MT45	Mined	3.65	52.4	23.6
MT78	Mined	4.07	134.7	1.8
MT79	Mined	4.42	289.1	3.6
MT81	Mined	3.98	110.2	1.8
MT01	Mined & Residences	3.86	84.9	29.1
MT69	Mined & Residences	3.49	37.2	18.2

APPENDIX 4. MAPS AND FIGURES

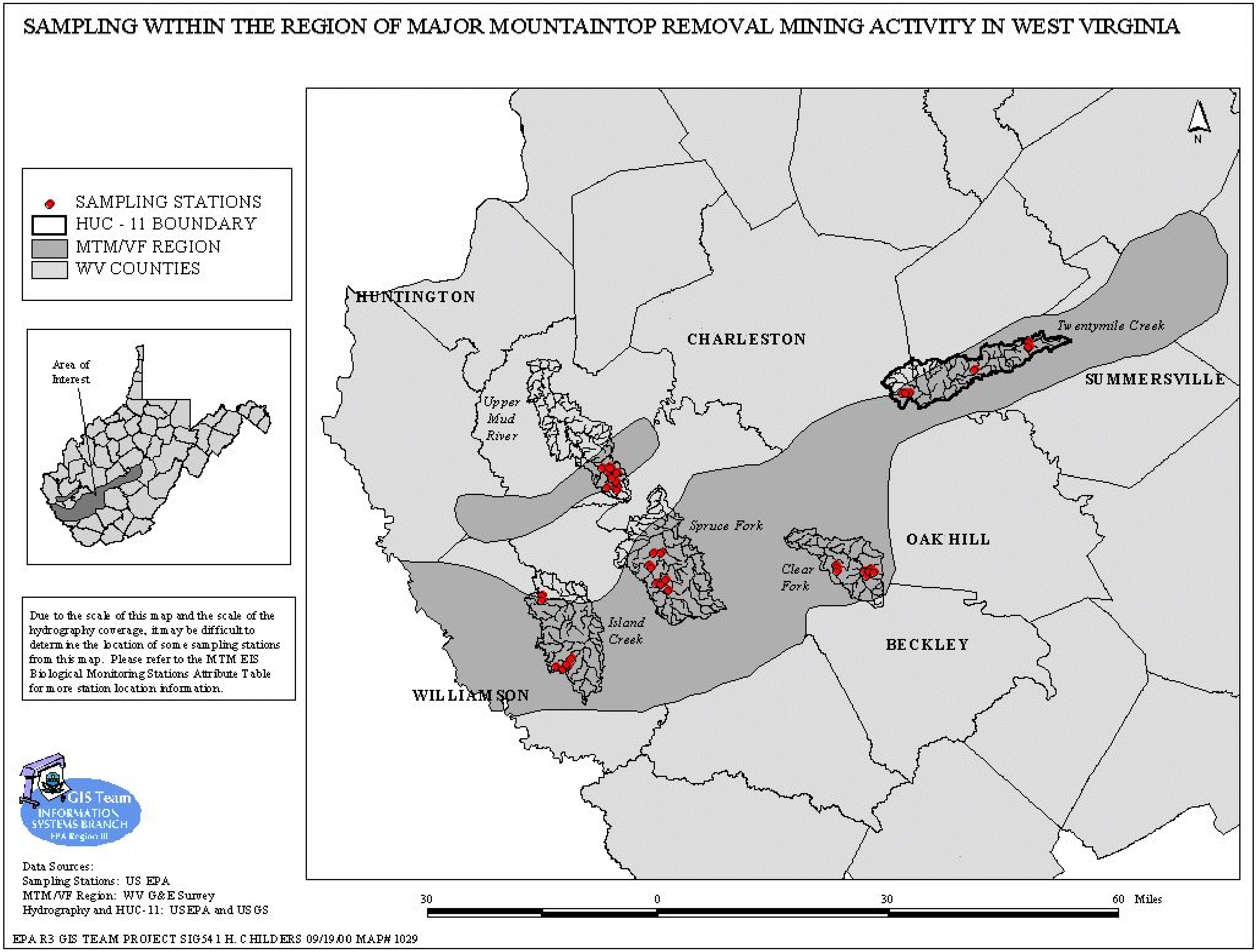


Figure 1. Sampling within the Region of Major Mountaintop Removal Mining Activity in West Virginia.

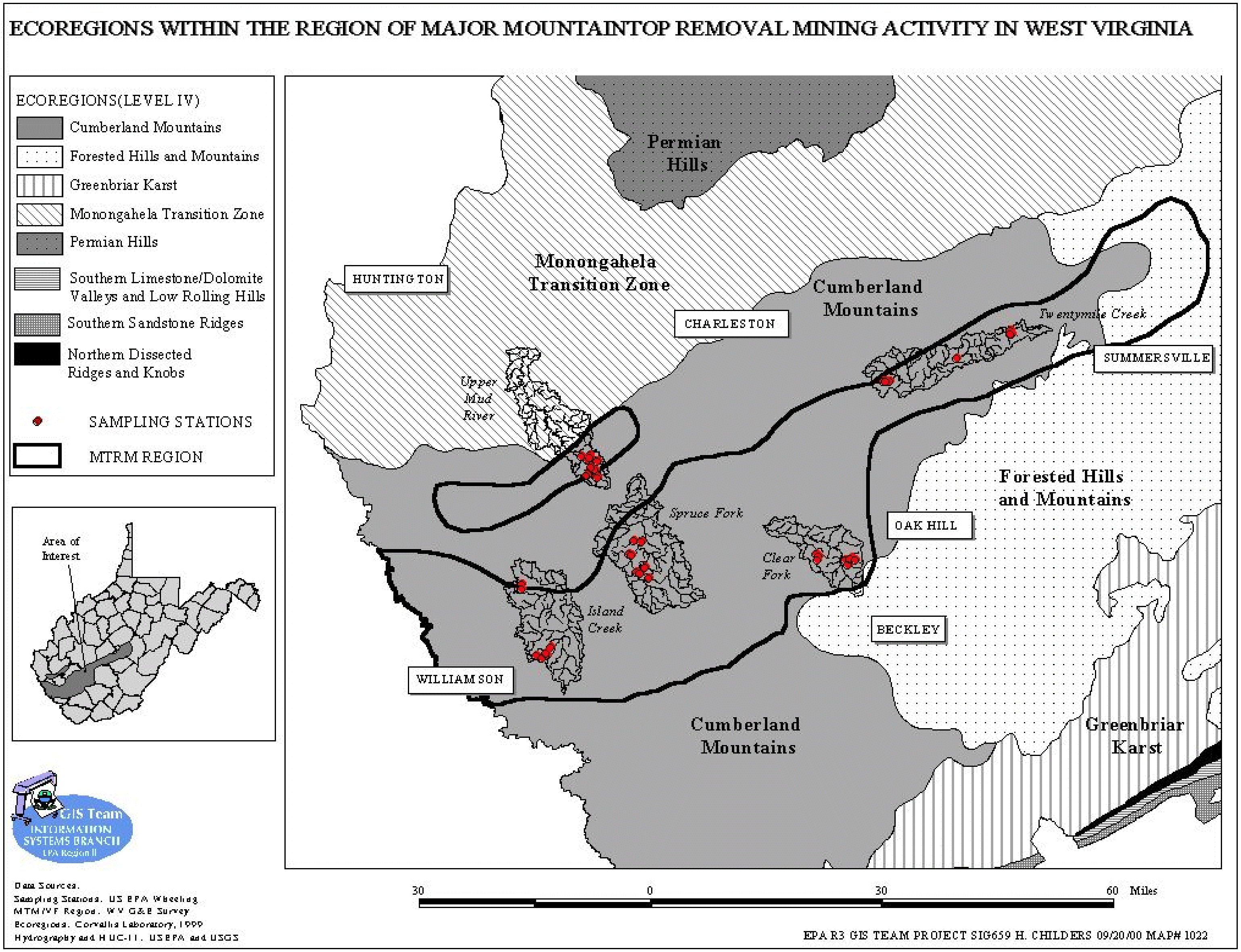


Figure 2. Ecoregions within the Region of Major Mountaintop Removal Mining Activity in West Virginia.

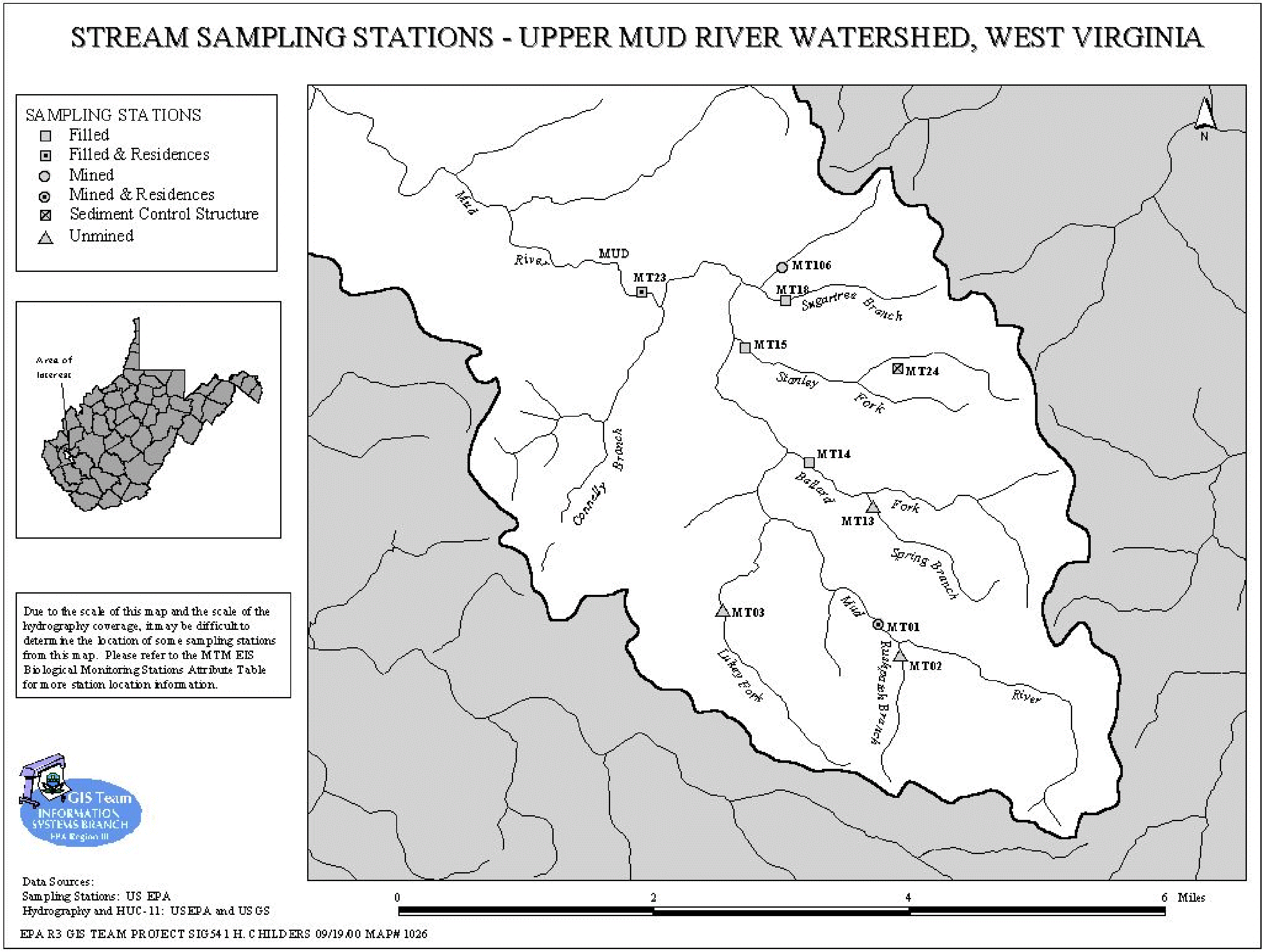


Figure 3. Stream Sampling Stations - Upper Mud River Watershed, West Virginia

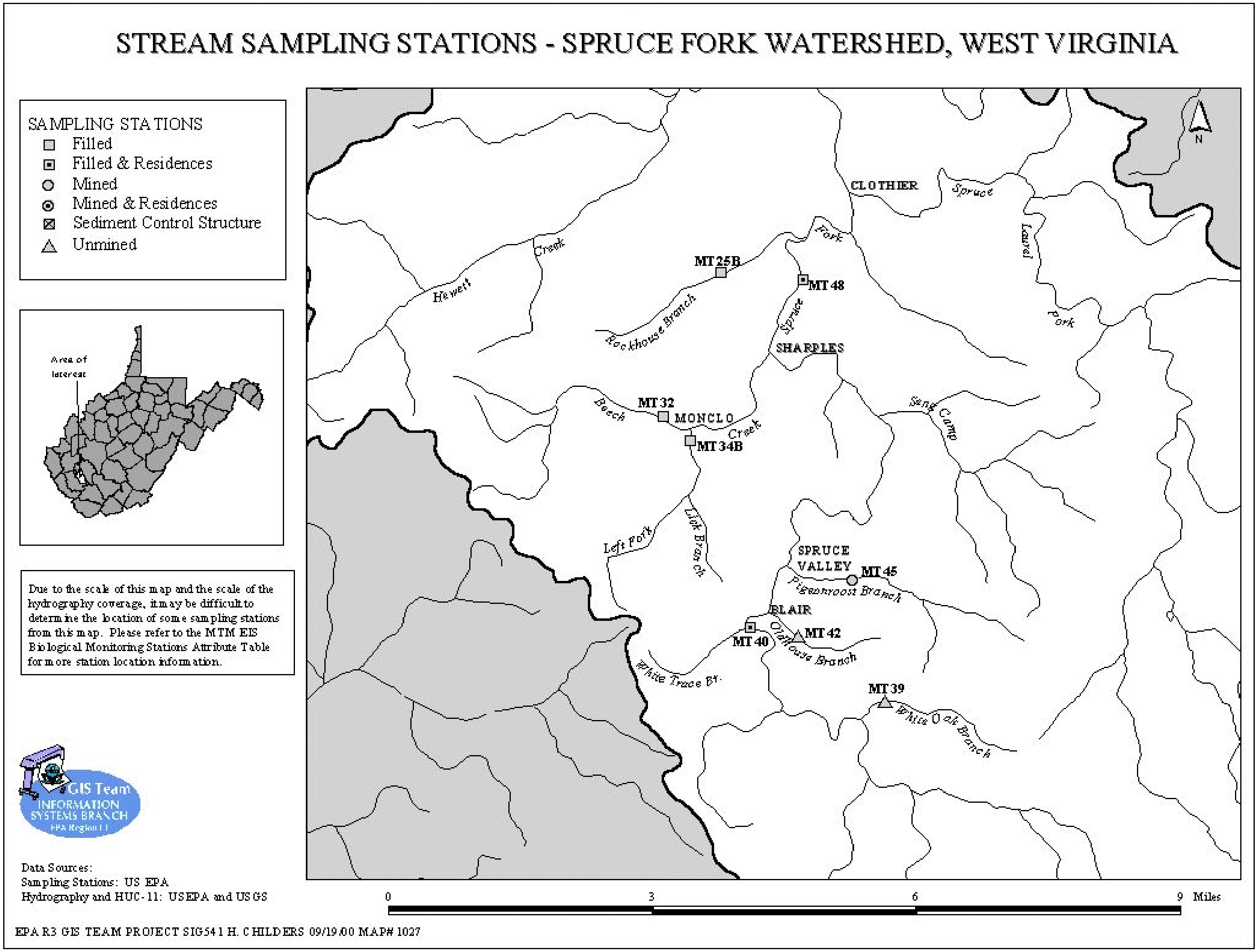


Figure 4. Stream Sampling Stations - Spruce Fork Watershed, West Virginia

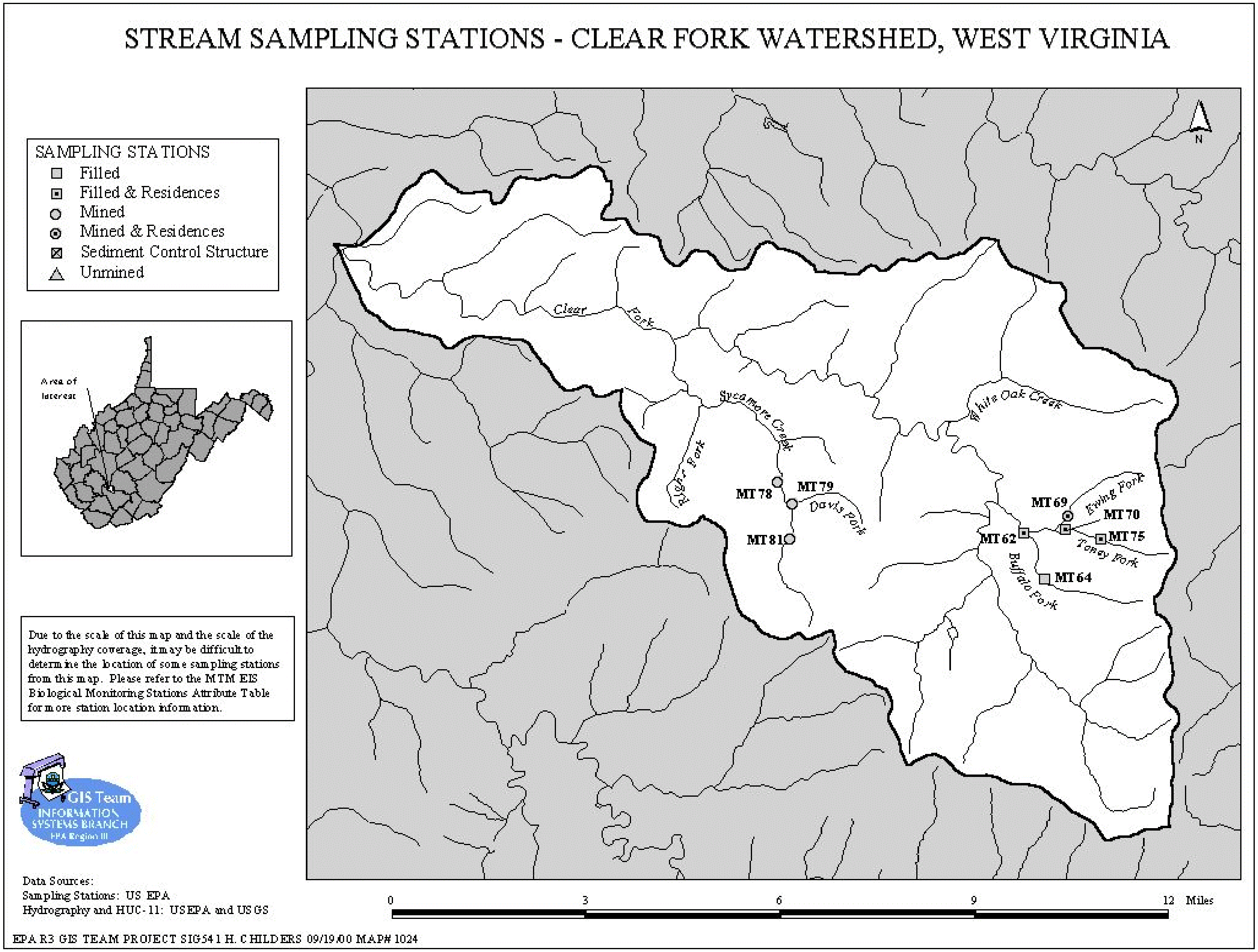


Figure 5. Stream Sampling Stations - Clear Fork Watershed, West Virginia

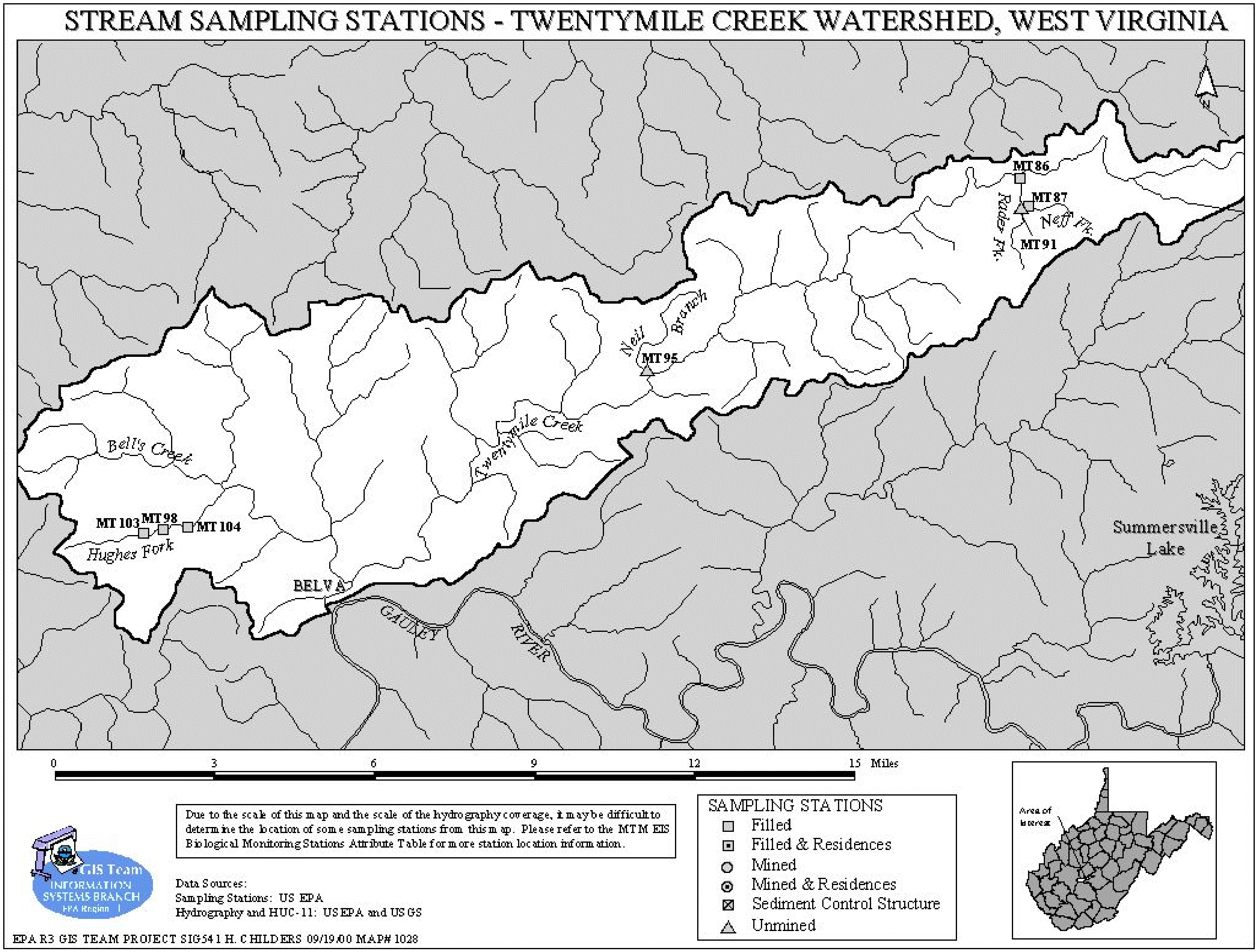


Figure 6. Stream Sampling Stations - Twentymile Creek Watershed, West Virginia

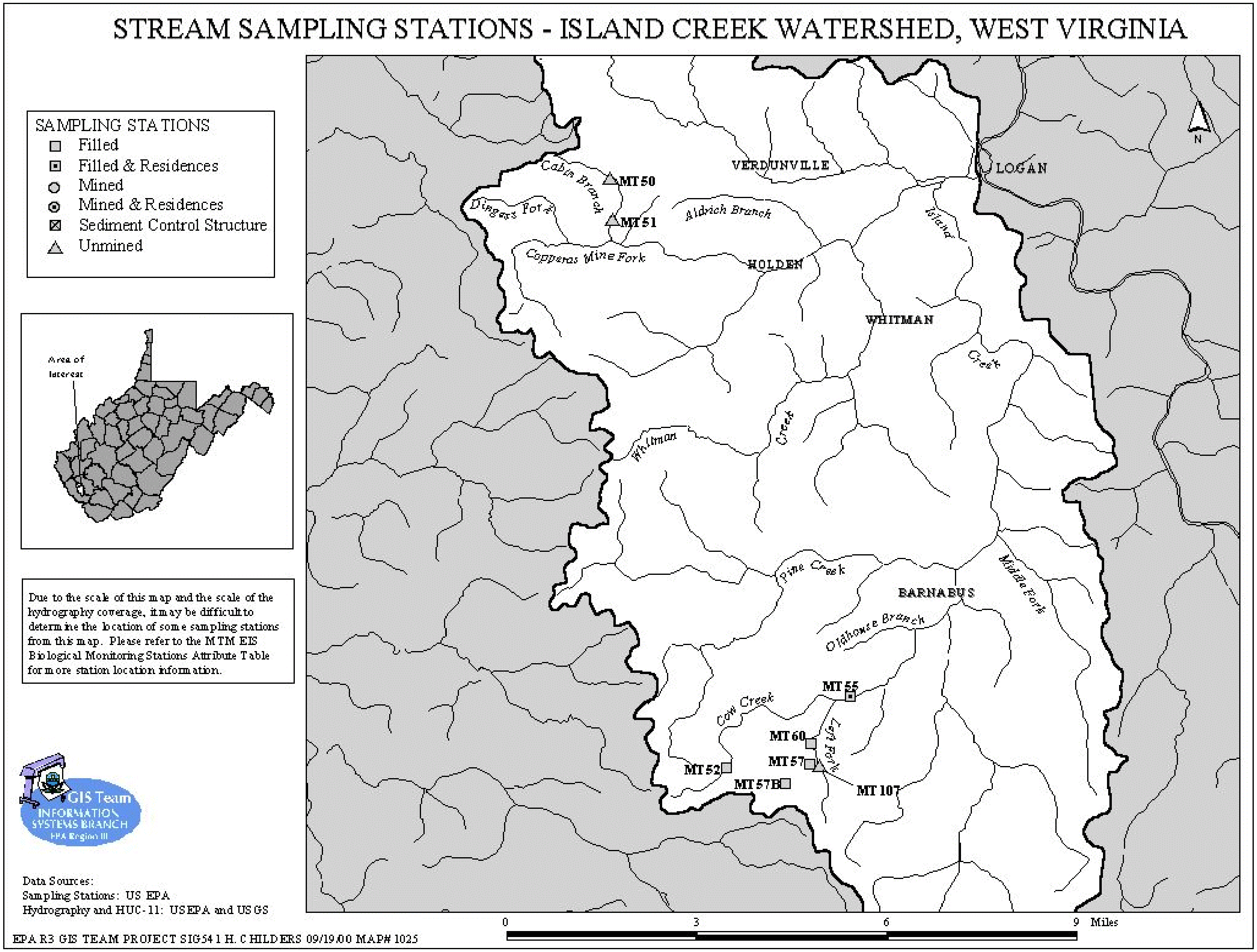


Figure 7. Stream Sampling Stations - Island Creek Watershed, West Virginia

Figure 8. Comparison of WV Stream Condition Index (SCI) Values
Spring 1999

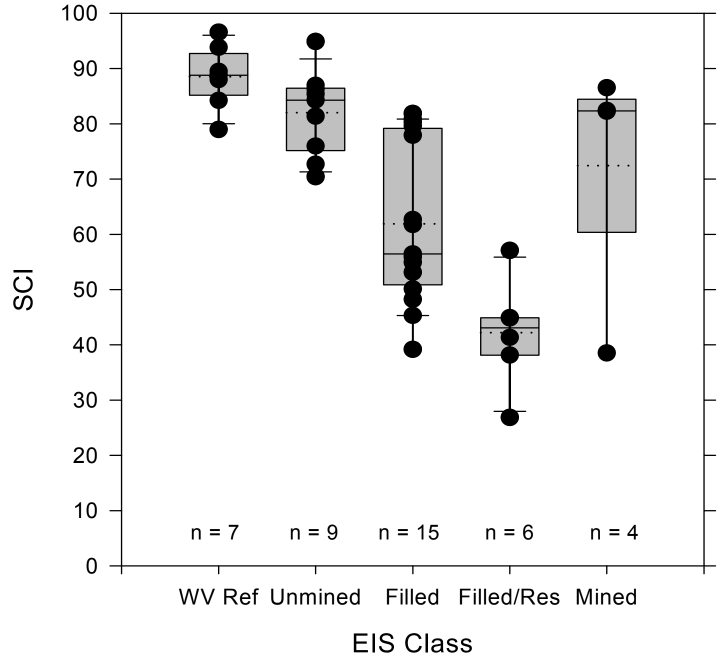


Figure 9. Comparison of Family-Level Total Taxa Values
Spring 1999

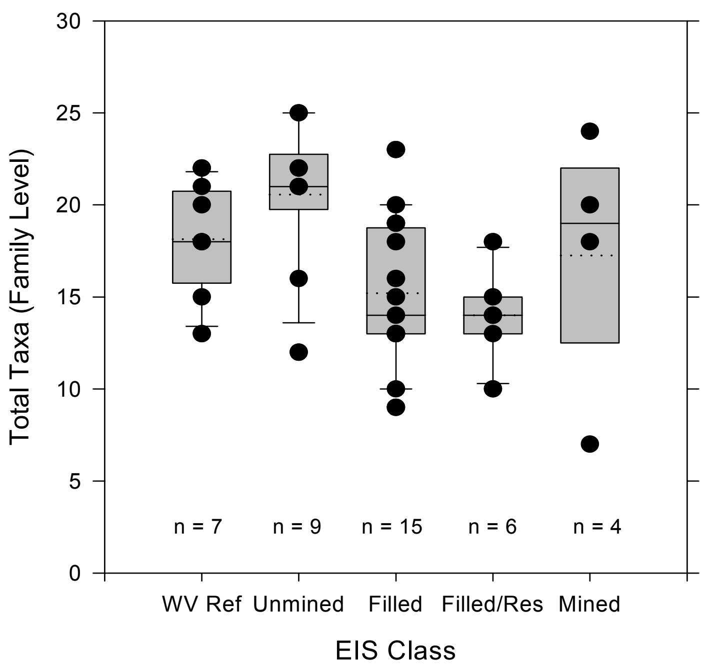


Figure 10. Comparison of Family-Level EPT Values
Spring 1999

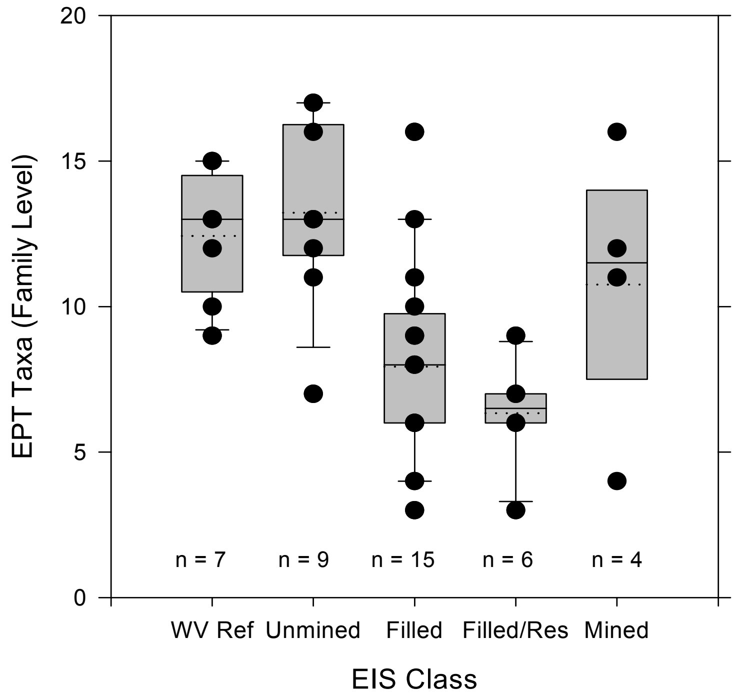


Figure 11. Comparison of %EPT Values
Spring 1999

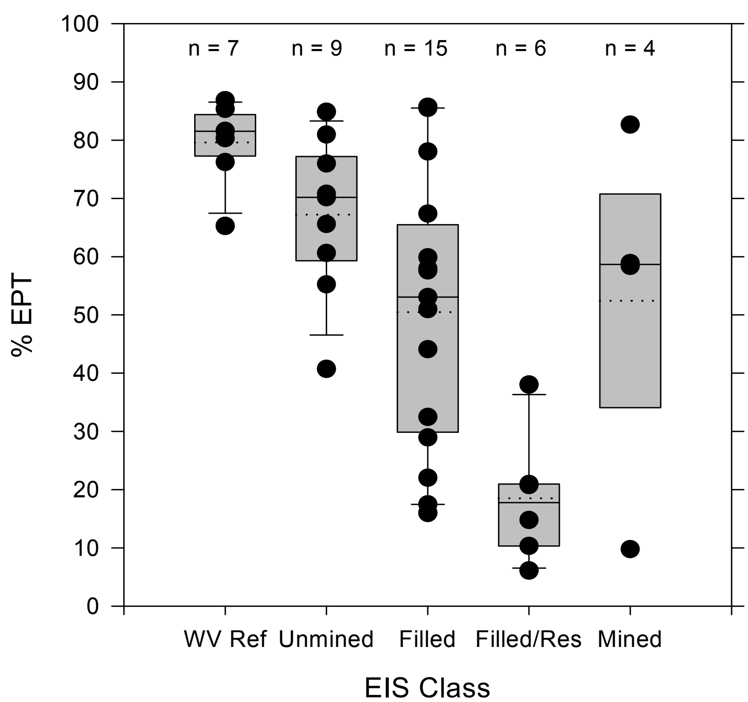


Figure 12. Comparison of HBI Values
Spring 1999

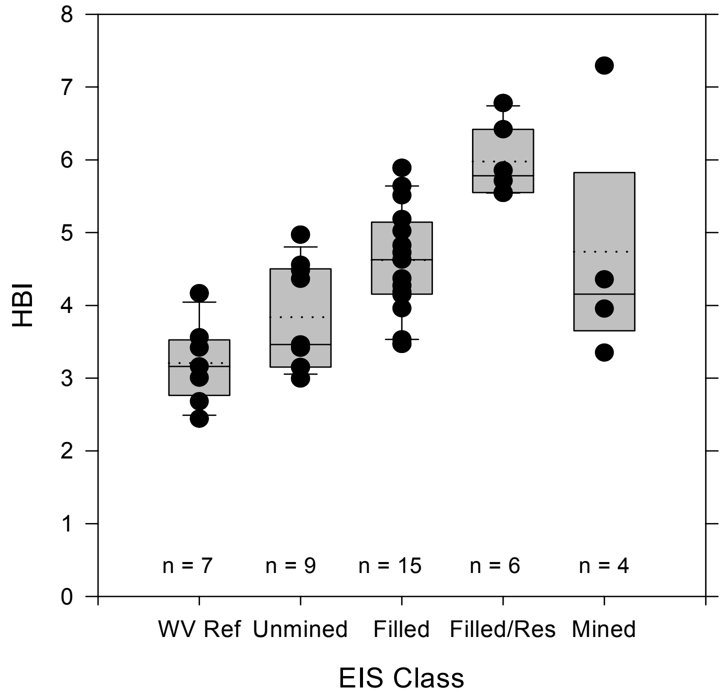


Figure 13. Comparison of % Two Dominant Familes Values
Spring 1999

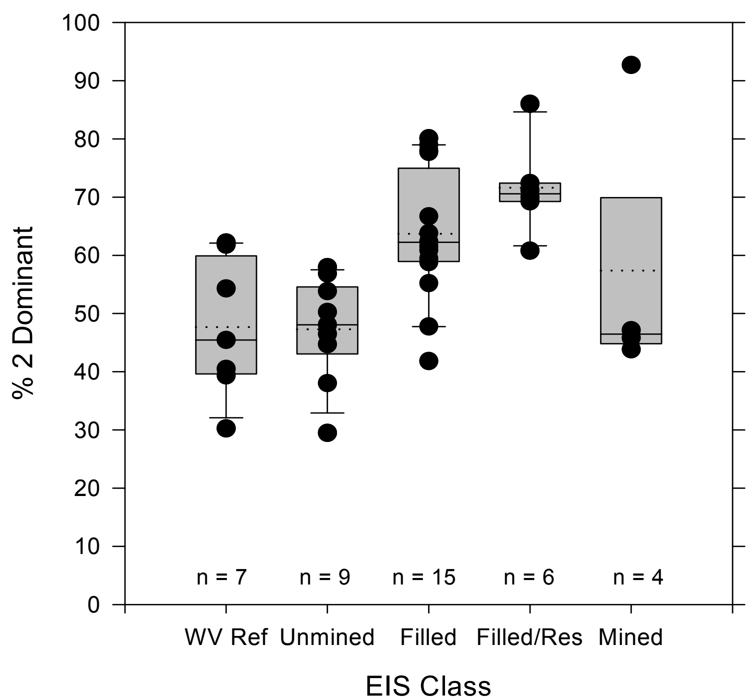


Figure 14. Comparison of Family-Level Mayfly Taxa Values
Spring 1999

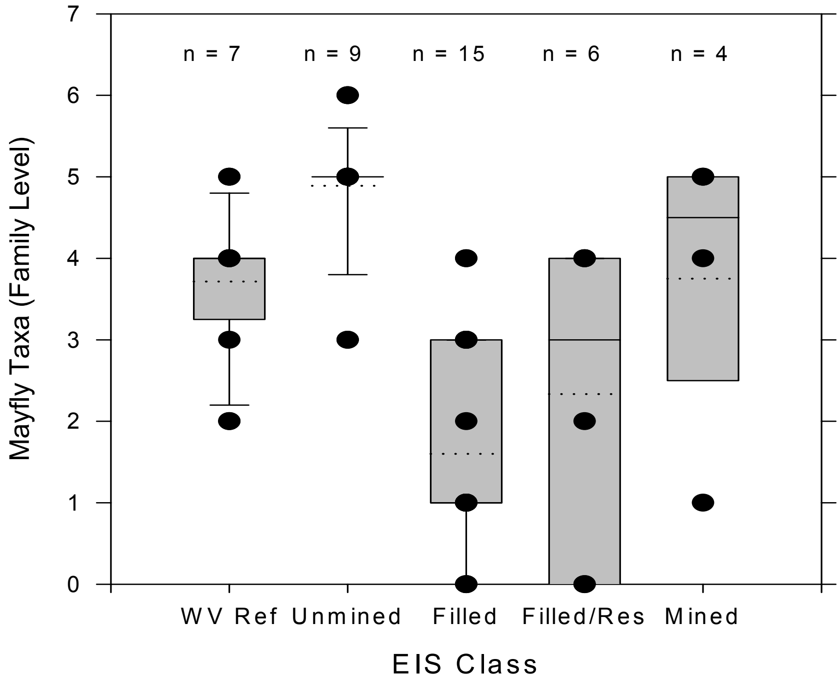


Figure 15. Comparison of % Mayfly Values
Spring 1999

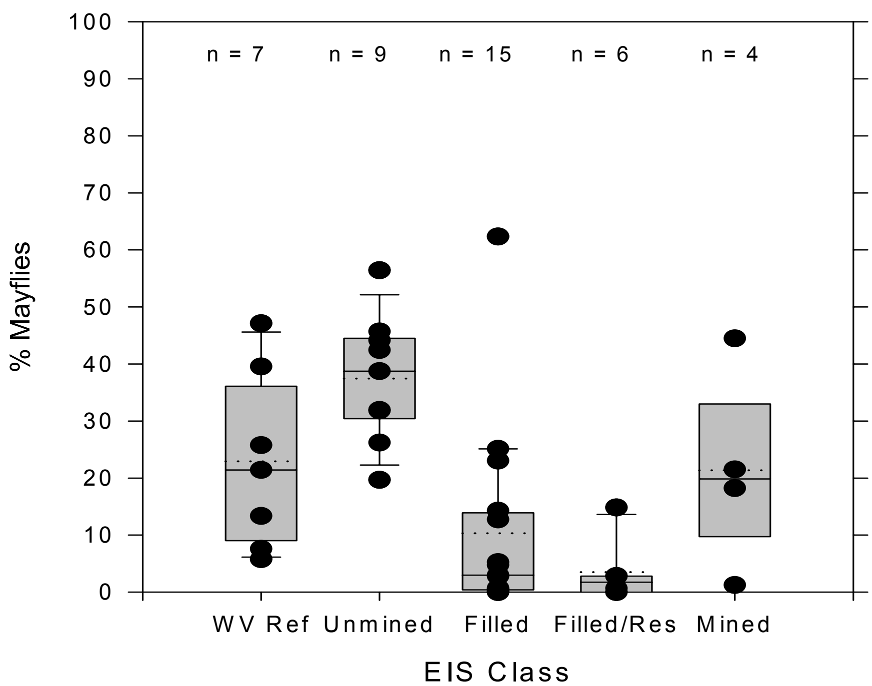


Figure 16. Comparison of % Chironomidae Values
Spring 1999

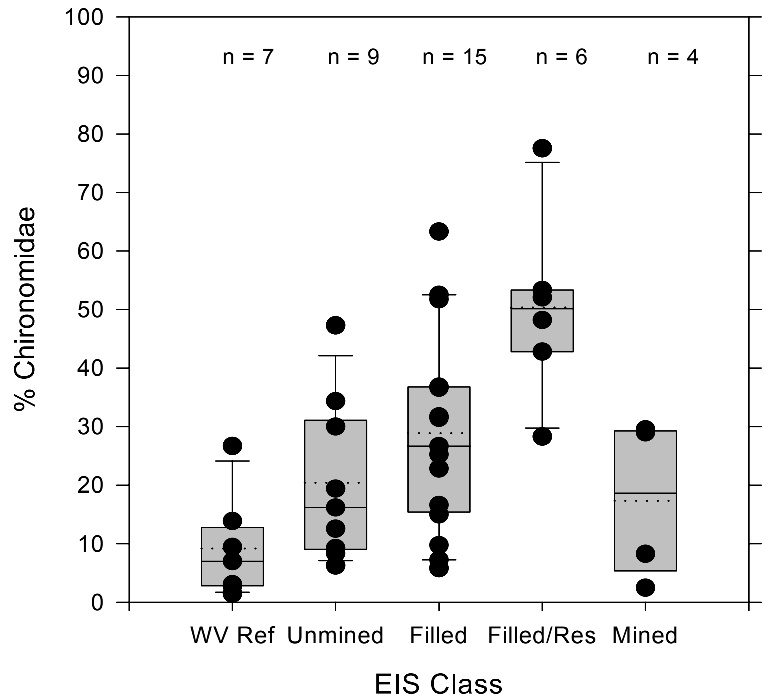


Figure 17. Comparison of WV Stream Condition Index Values Summer 1999

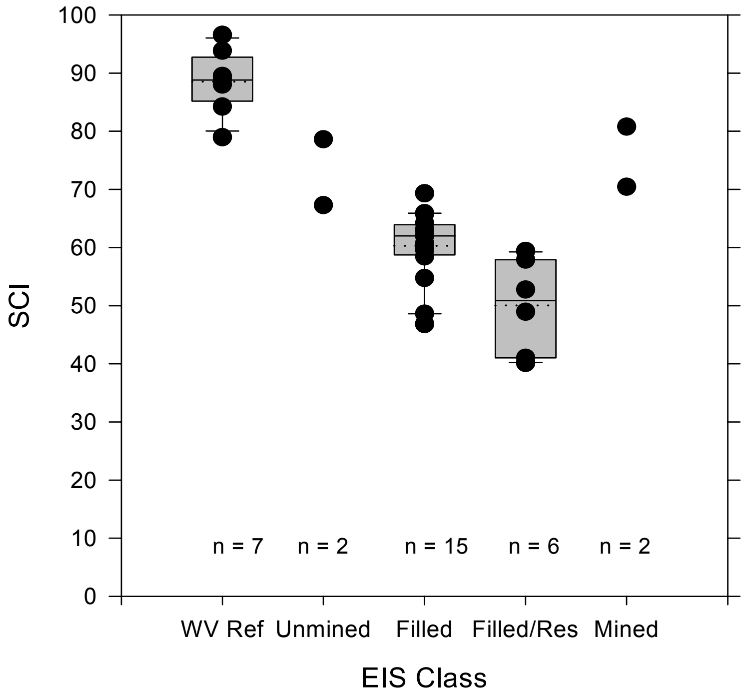


Figure 18. Comparison of Family-Level Total Taxa Vaues Summer 1999

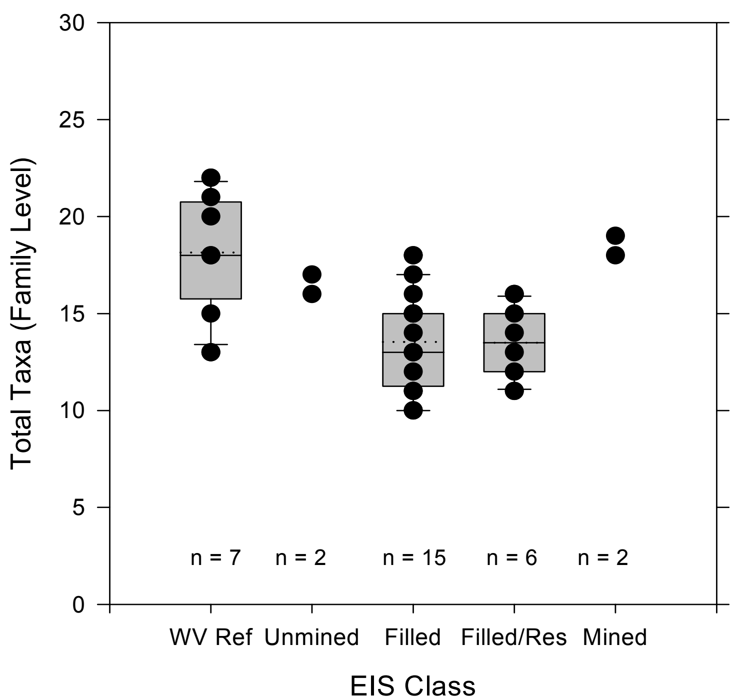


Figure 19. Comparison of Family-Level EPT Taxa Values
Summer 1999

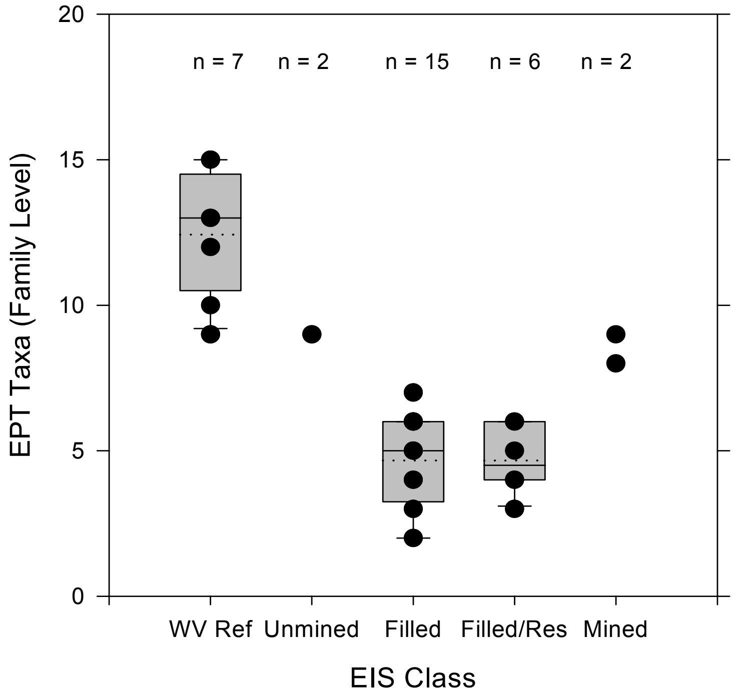


Figure 20. Comparison of % EPT Values
Summer 1999

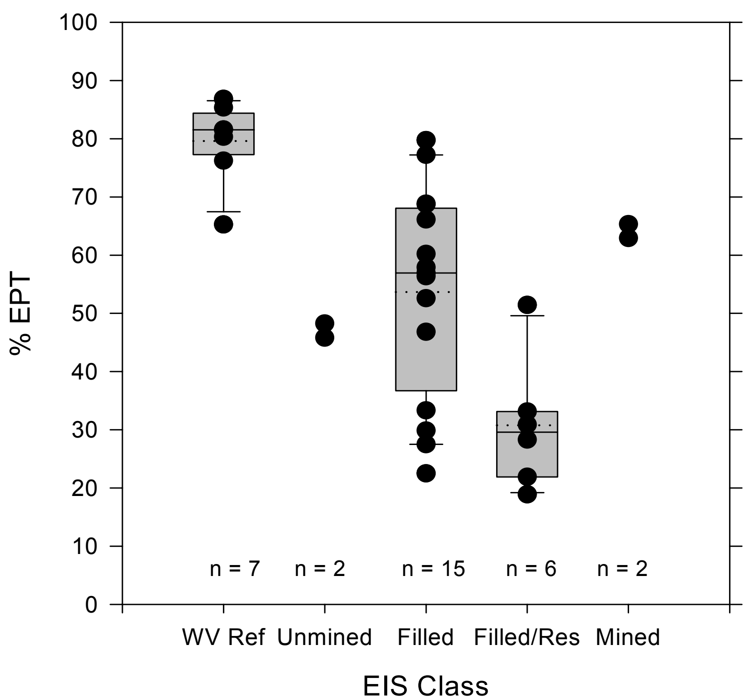


Figure 21. Comparison of HBI Values
Summer 1999

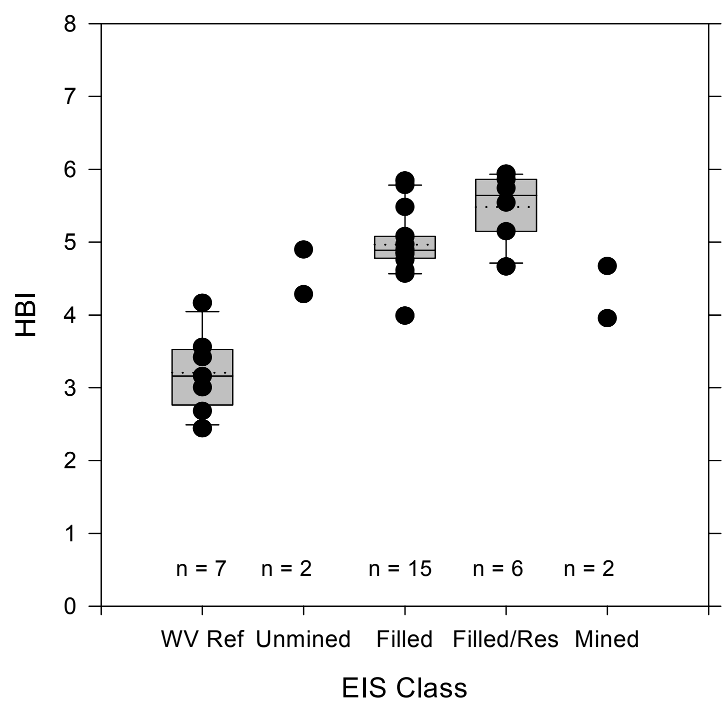


Figure 22. Comparison of % Two Dominant Families Values
Summer 1999

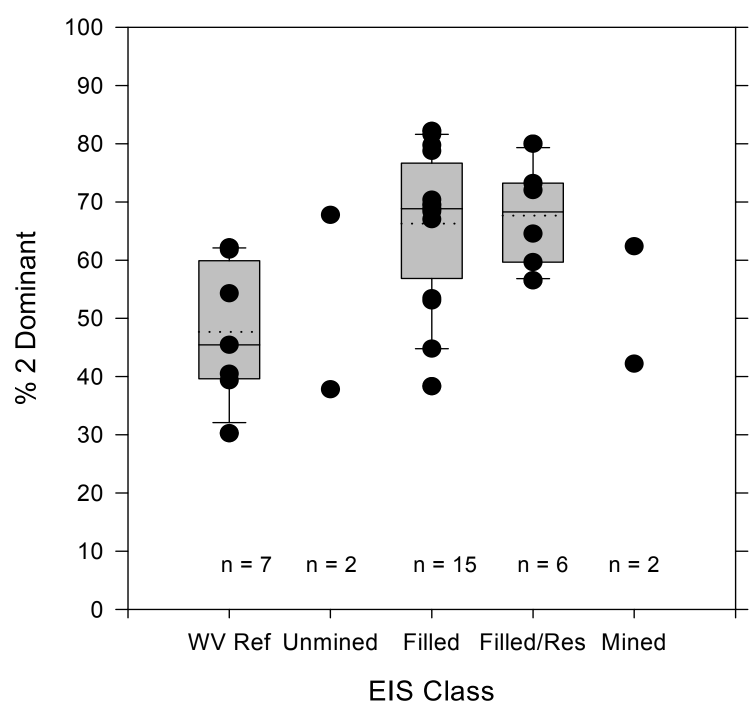


Figure 23. Comparison of Family-Level Mayfly Taxa Values
Summer 1999

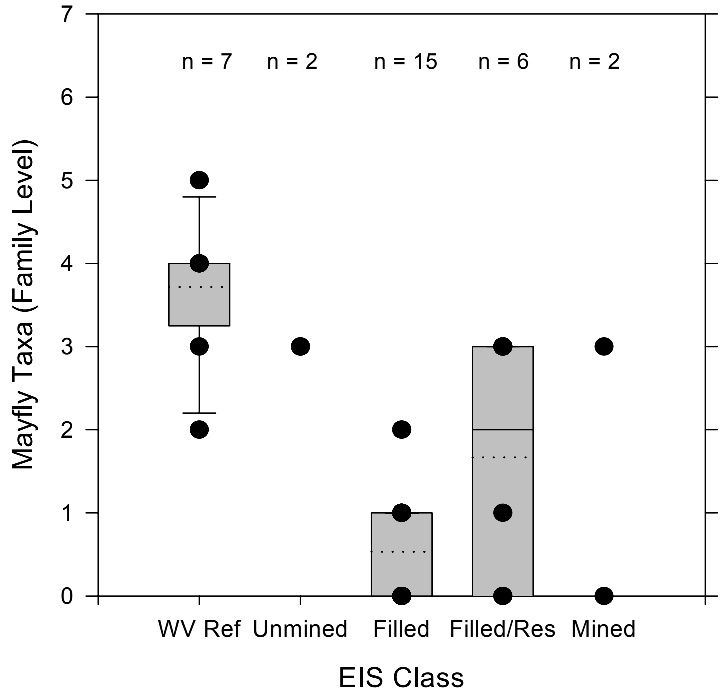


Figure 24. Comparison of % Mayfly Values
Summer 1999

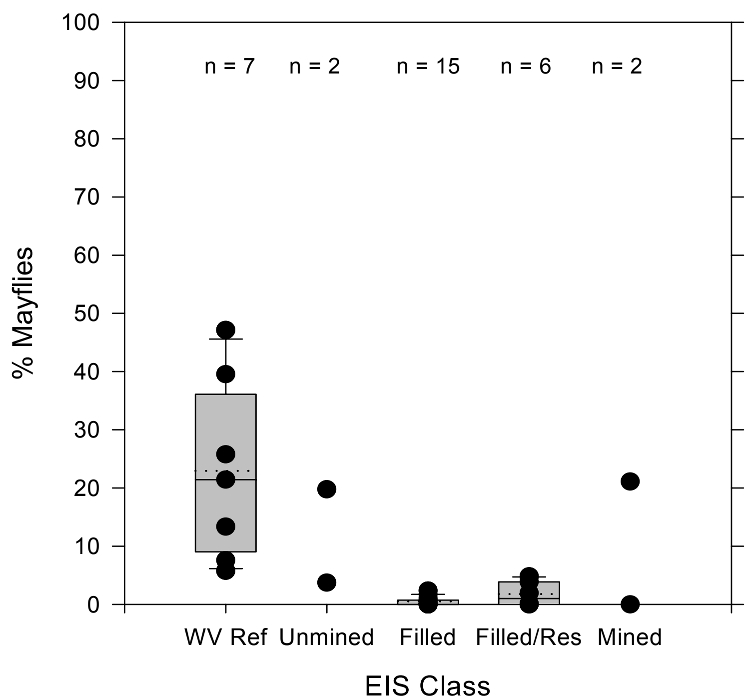


Figure 25. Comparison of % Chironomidae Values
Summer 1999

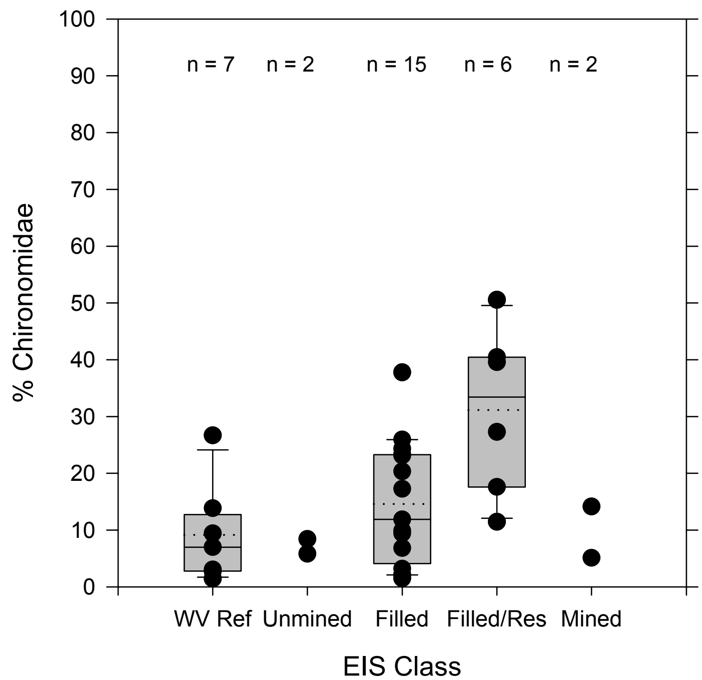


Figure 26. Comparison of WV Stream Condition Index Values
Fall 1999

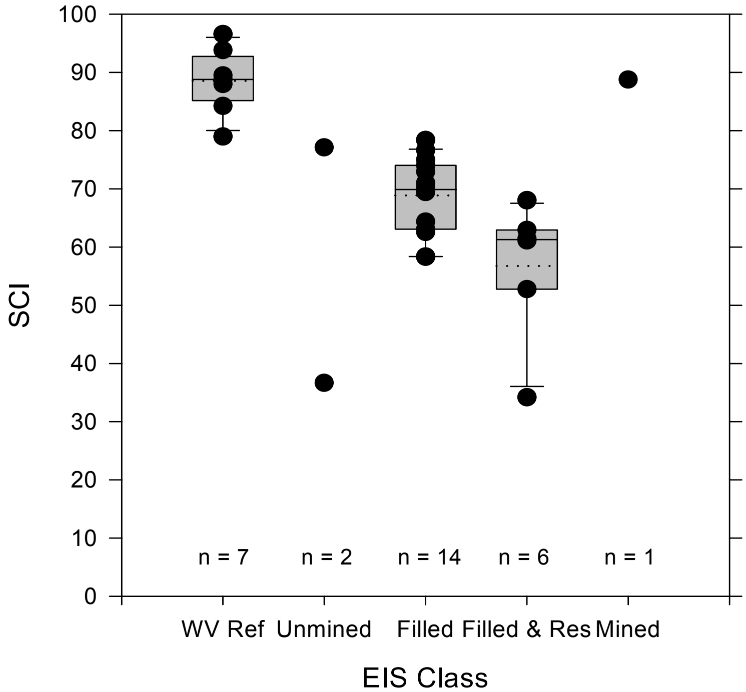


Figure 27. Comparison of Family-Level Total Taxa Values
Fall 1999

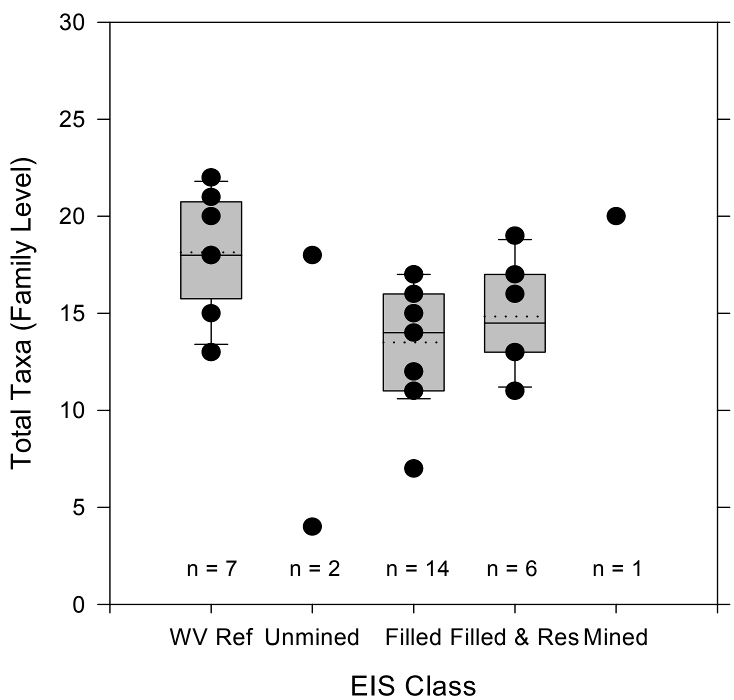


Figure 28. Comparison of Family-Level EPT Taxa Values
Fall 1999

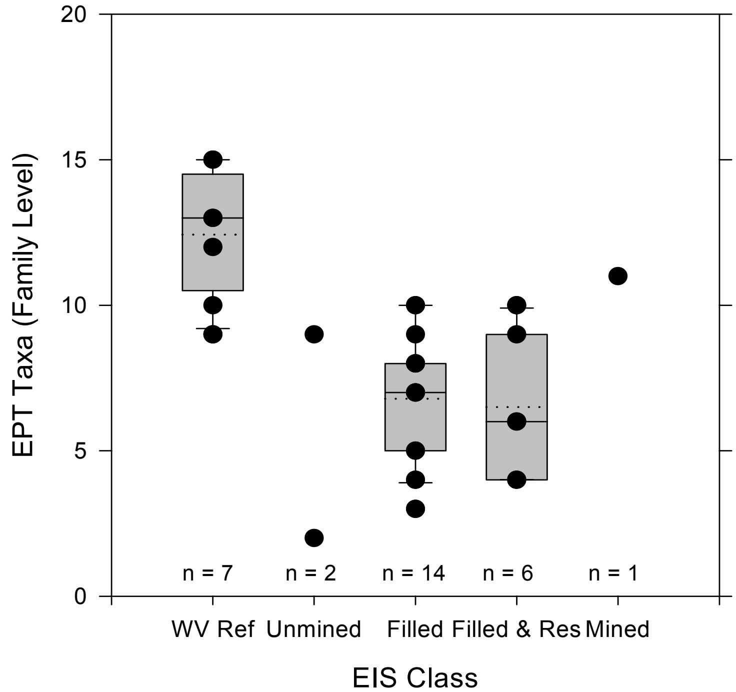


Figure 29. Comparison of % EPT Values
Fall 1999

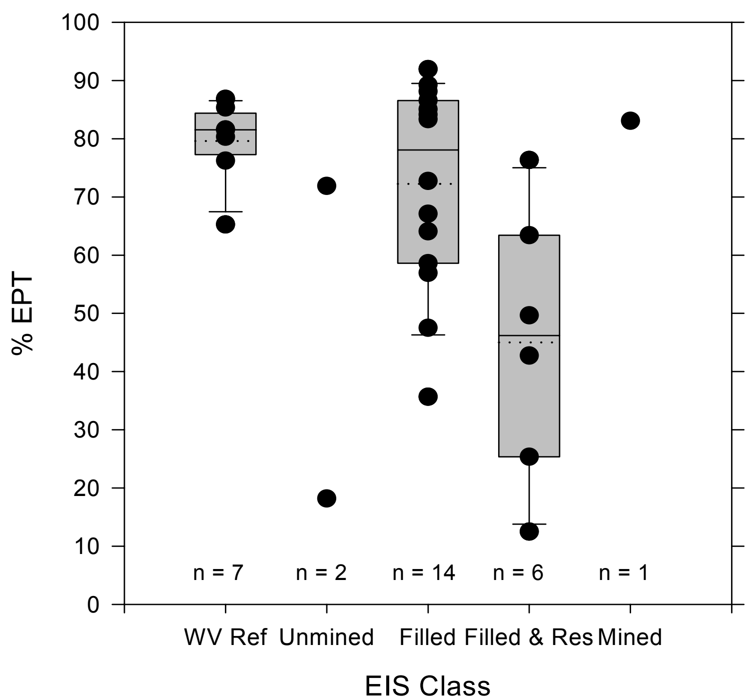


Figure 30. Comparison of HBI Values
Fall 1999

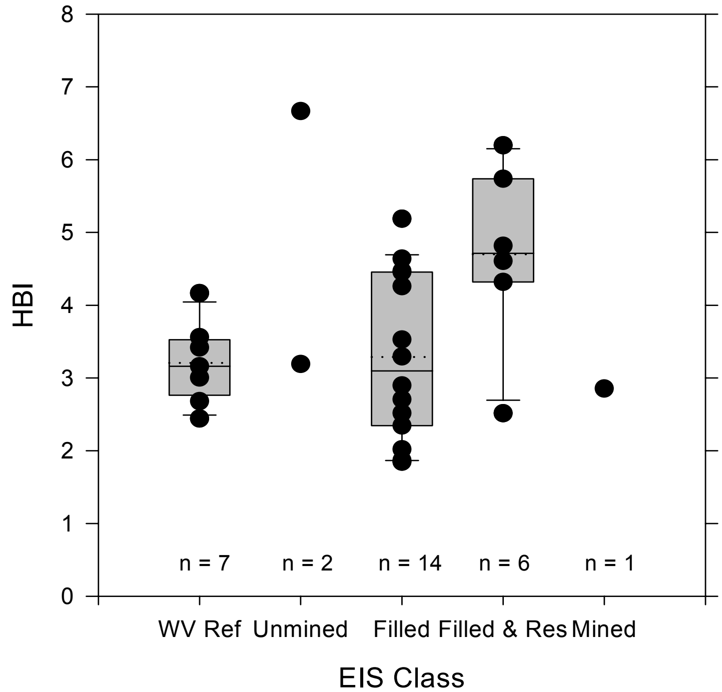


Figure 31. Comparison of %2Dominant Families Values
Fall 1999

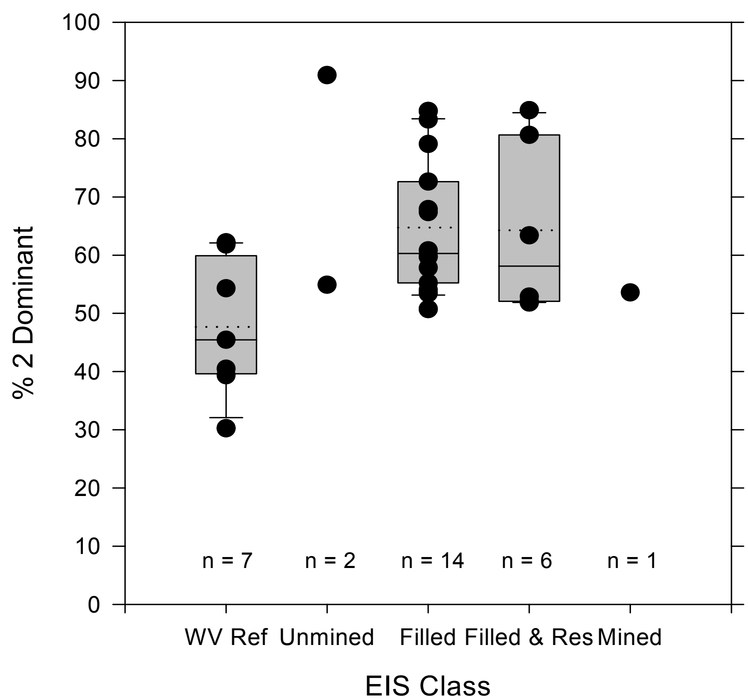


Figure 32. Comparison of Family-Level Mayfly Taxa Values
Fall 1999

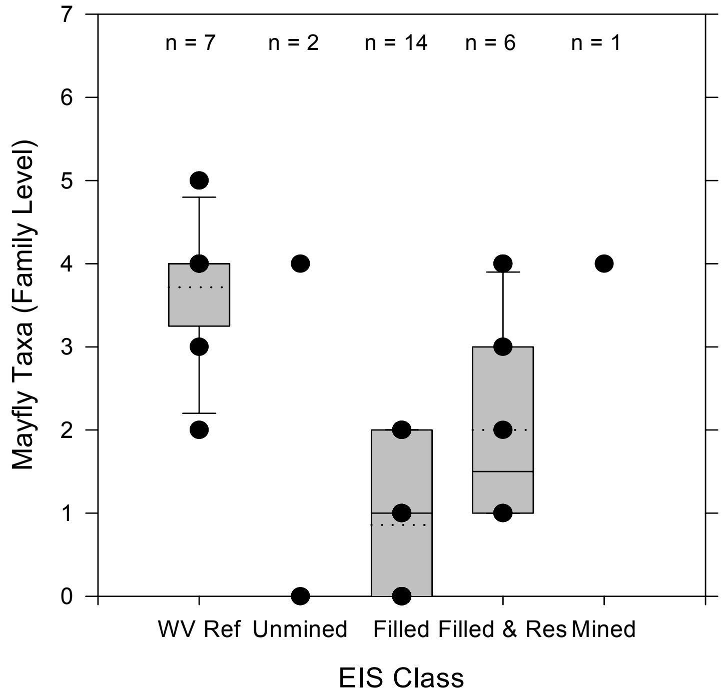


Figure 33. Comparison of % Mayfly Values
Fall 1999

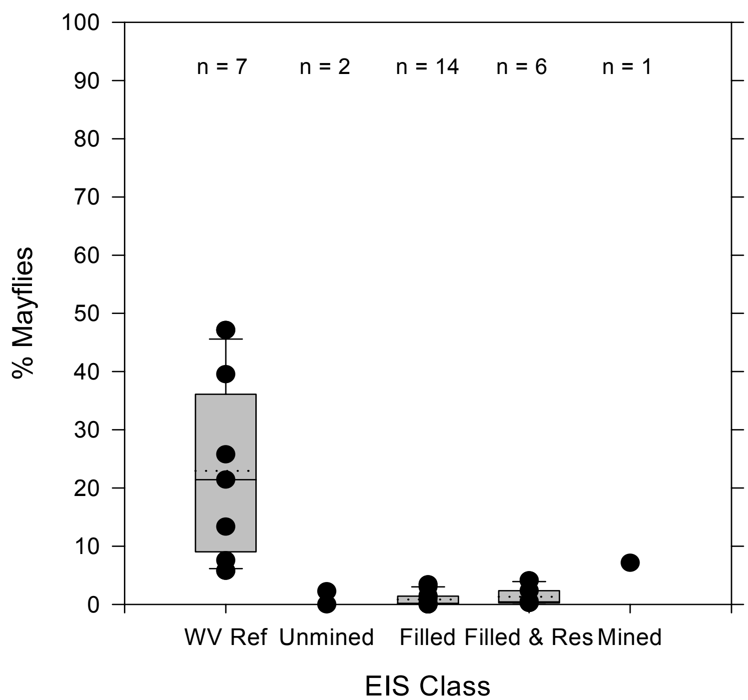


Figure 34. Comparison of % Chironomidae Values
Fall 1999

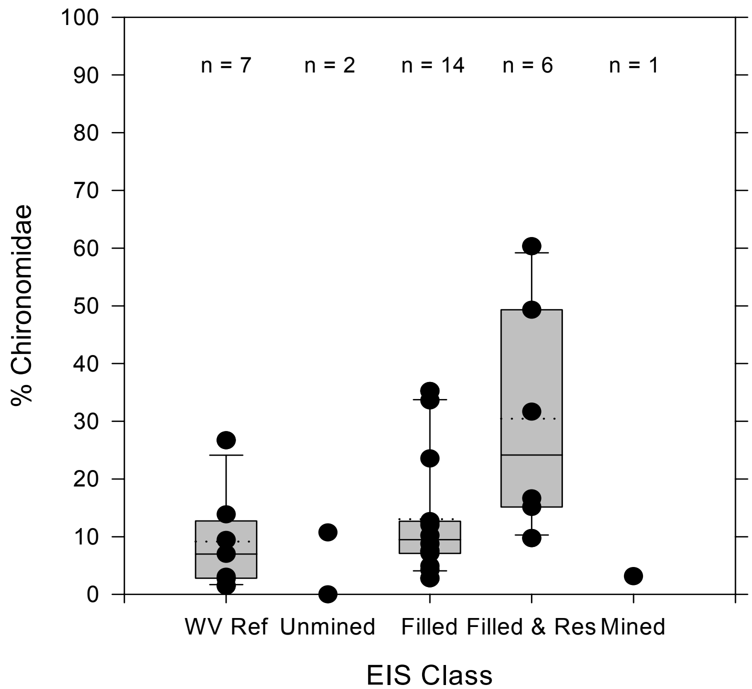


Figure 35. Comparison of WV Stream Condition Index (SCI) Values
Winter 2000

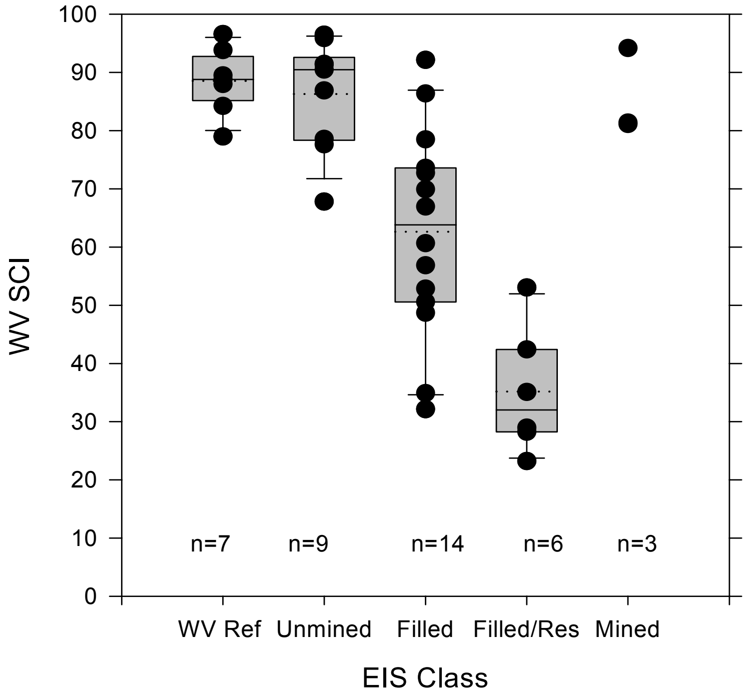


Figure 36. Comparison of Family-Level Total Taxa Values
Winter 2000

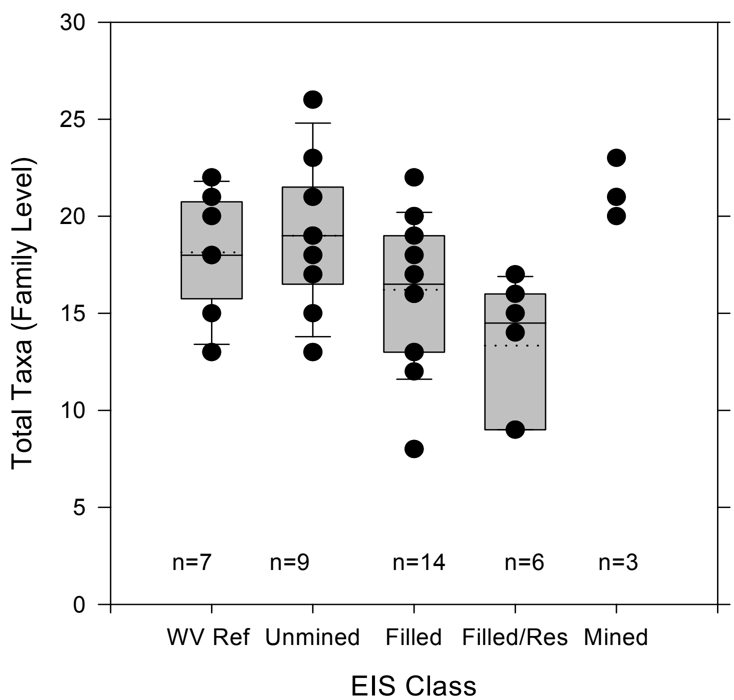


Figure 37. Comparison of Family-Level EPT Taxa Values
Winter 2000

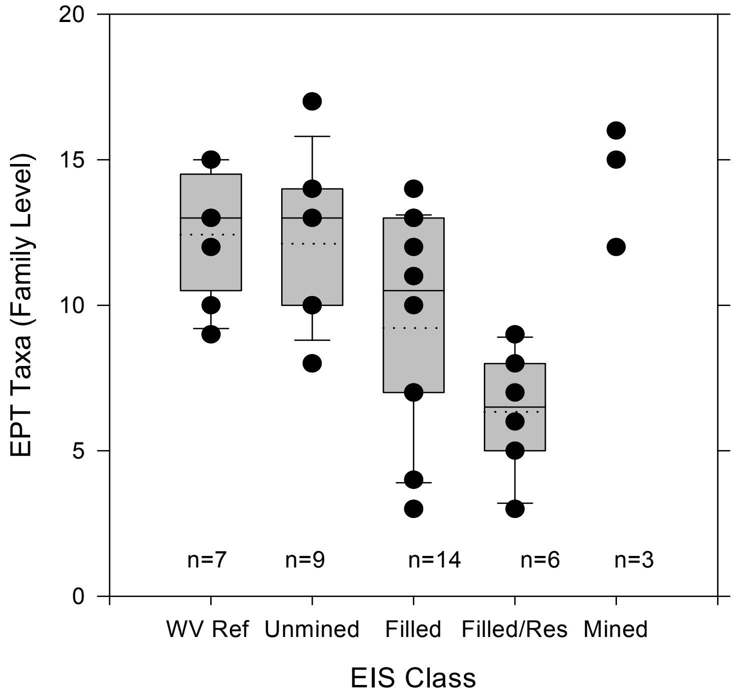


Figure 38. Comparison of % EPT Values
Winter 2000

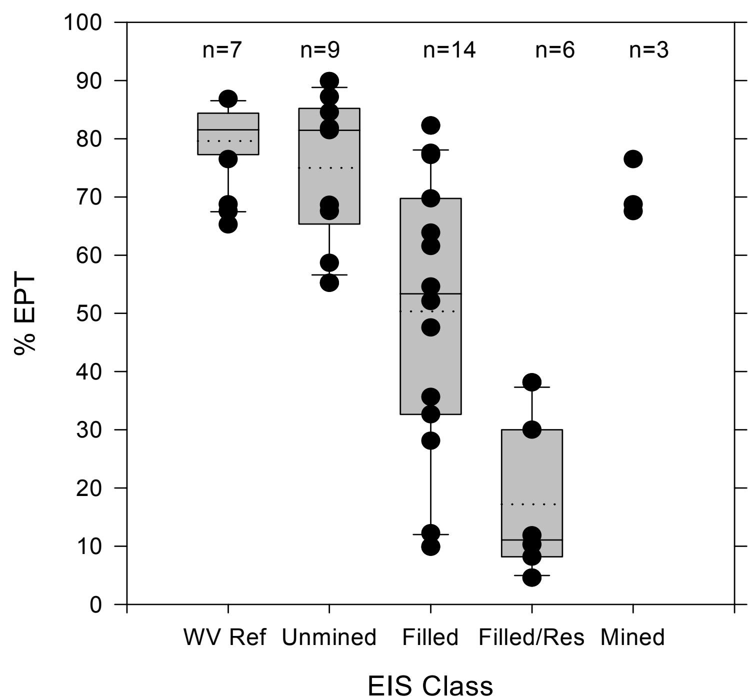


Figure 39. Comparison of HBI Values
Winter 2000

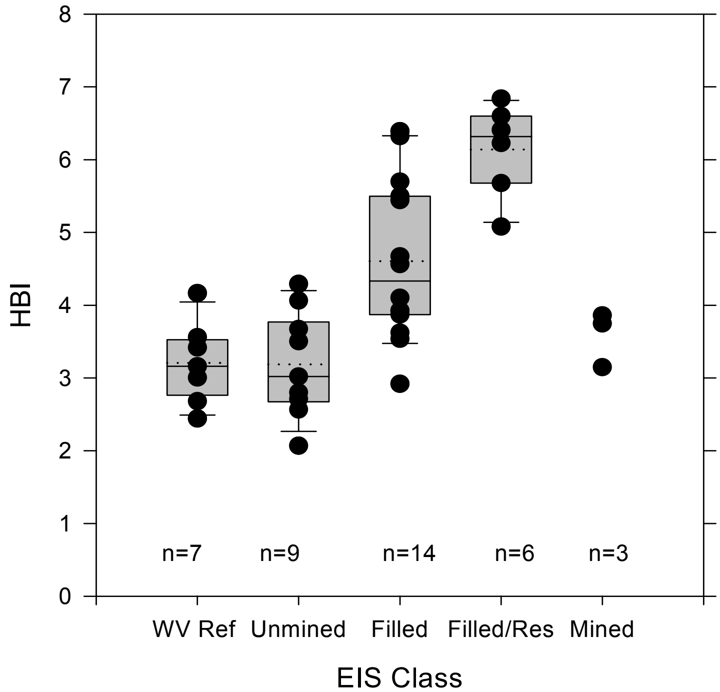


Figure 40. Comparison of % Two Dominant Families Values
Winter 2000

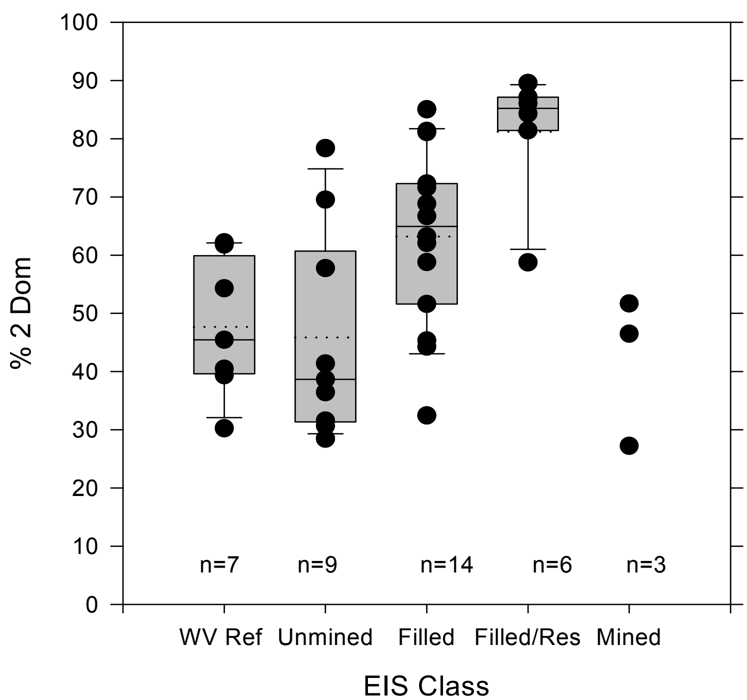


Figure 41. Comparison of Family-Level Mayfly Taxa Values
Winter 2000

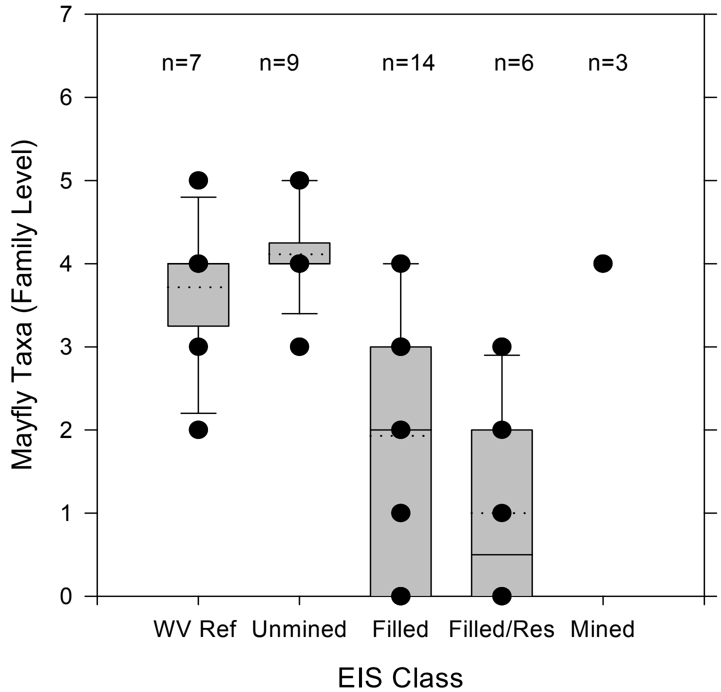


Figure 42. Comparison of % Mayfly Values
Winter 2000

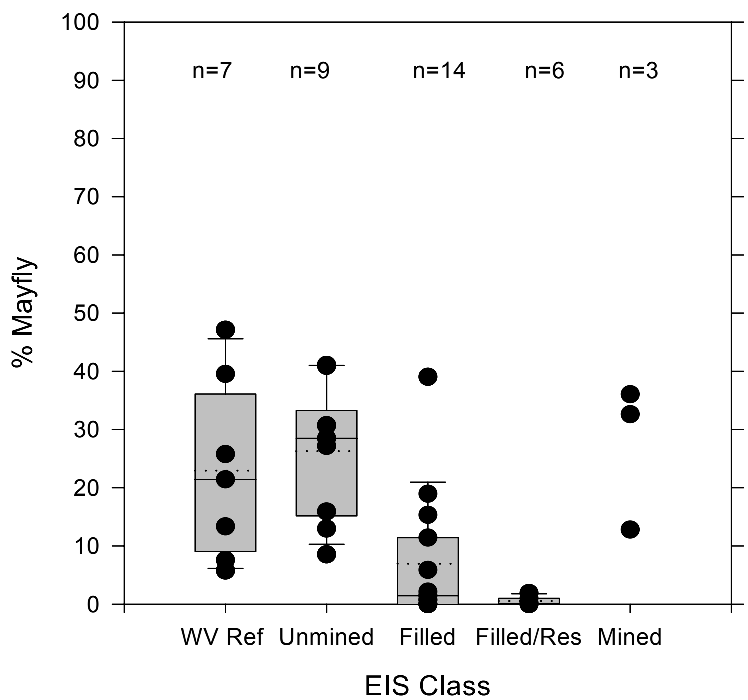


Figure 43. Comparison of % Chironomidae Values Winter 2000

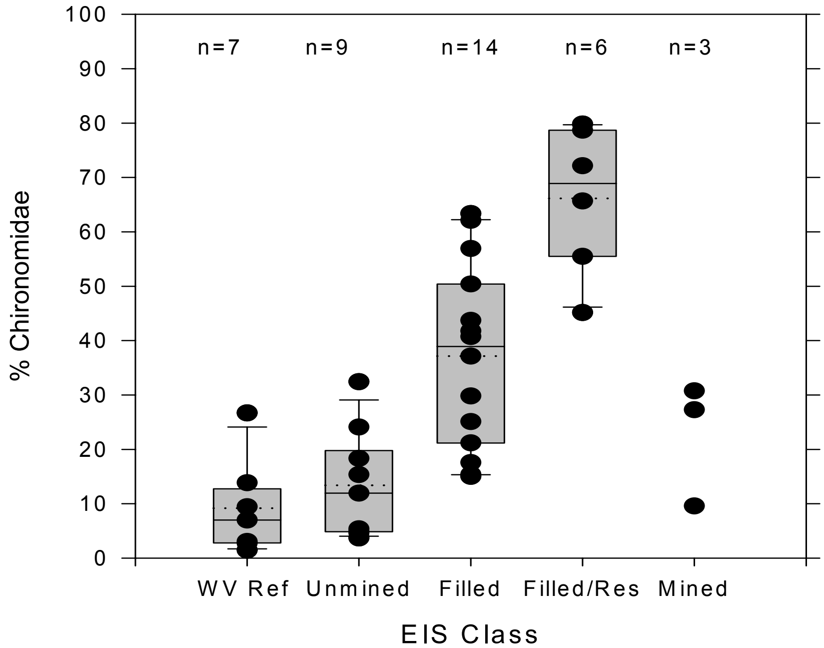


Figure 44. Comparison of WV Stream Condition Index (SCI) Values
Spring 2000

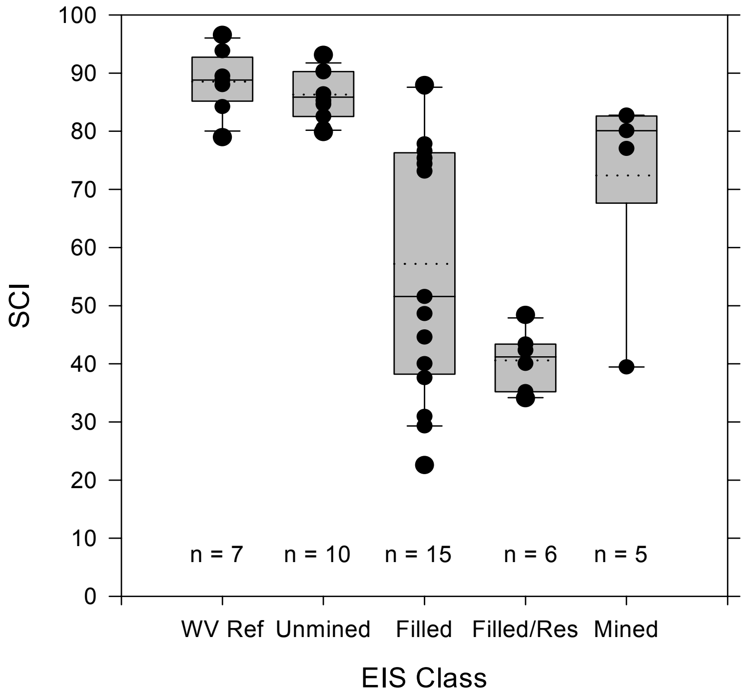


Figure 45. Comparison of Family-Level Total Taxa Values
Spring 2000

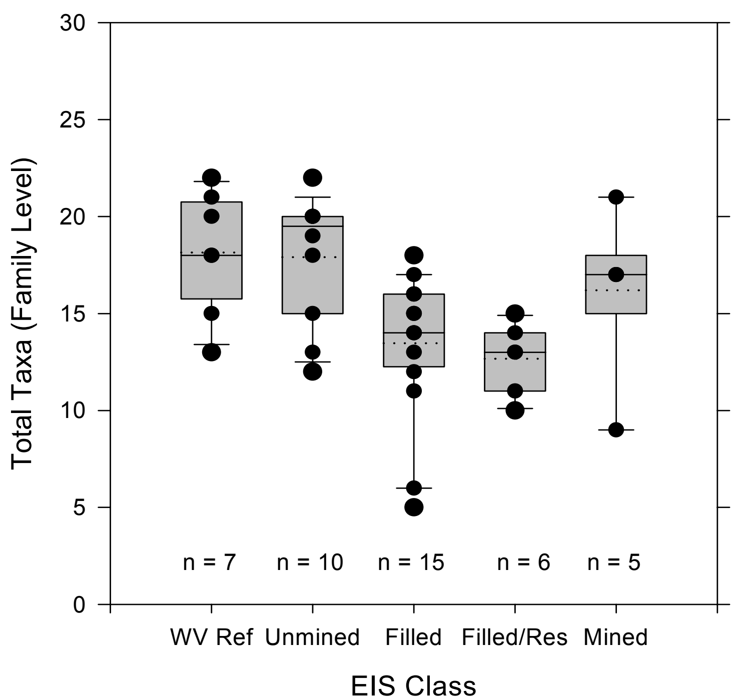


Figure 46. Comparison of Family-Level EPT Values
Spring 2000

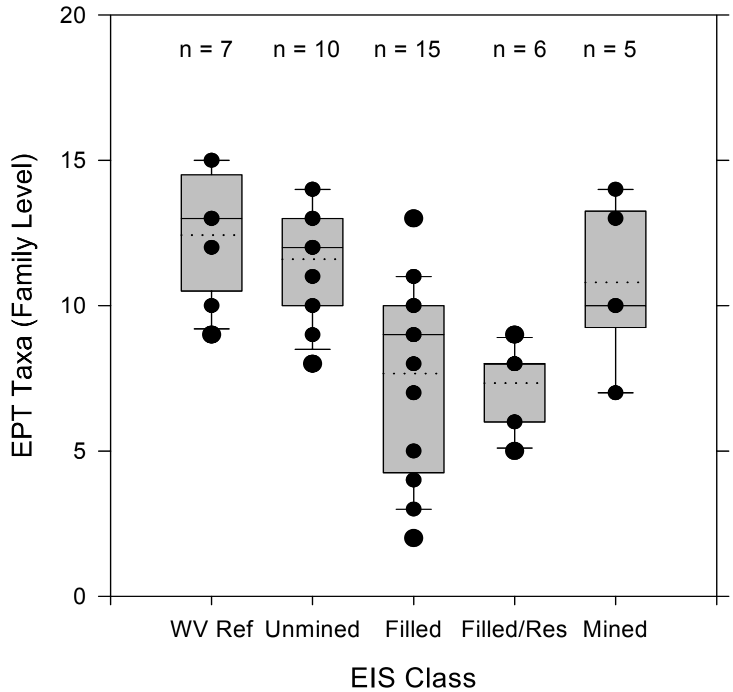


Figure 47. Comparison of %EPT Values
Spring 2000

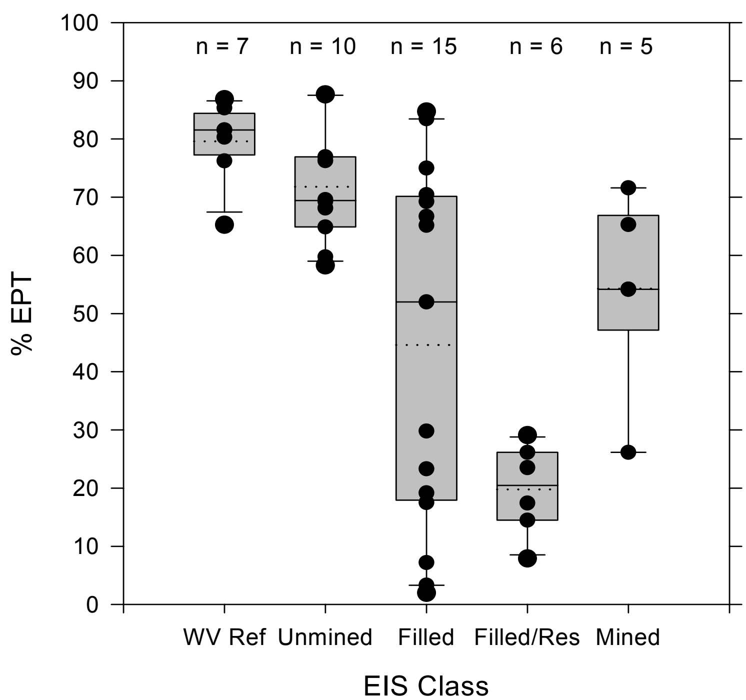


Figure 48. Comparison of HBI Values
Spring 2000

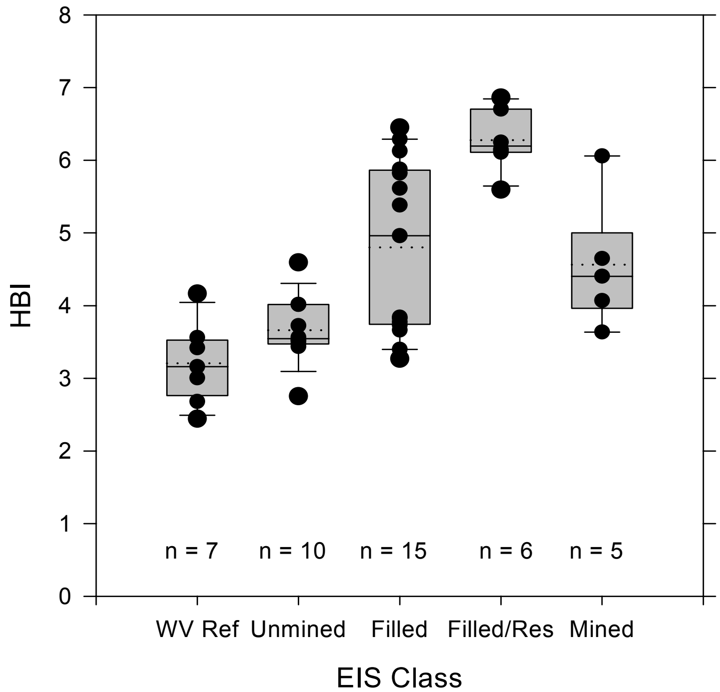


Figure 49. Comparison of % Two Dominant Families Values
Spring 2000

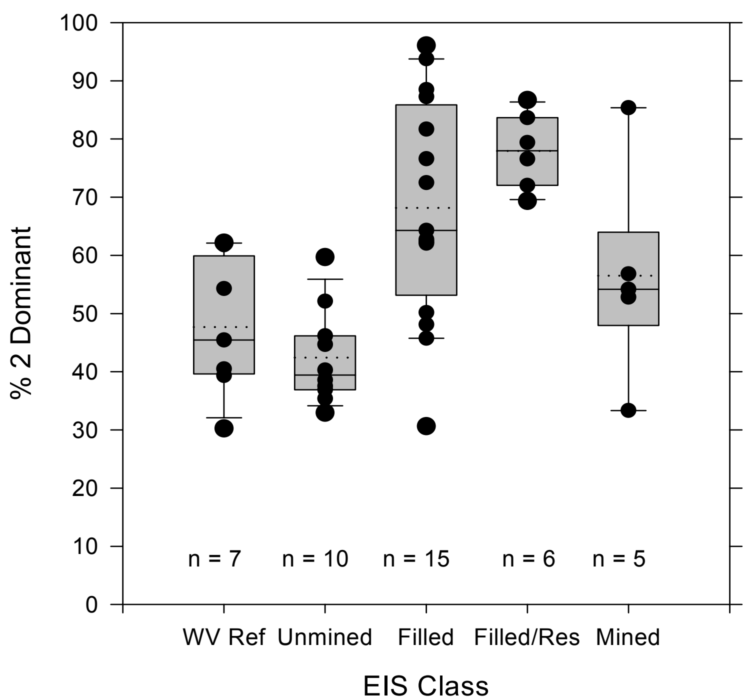


Figure 50. Comparison of Family-Level Mayfly Taxa Values
Spring 2000

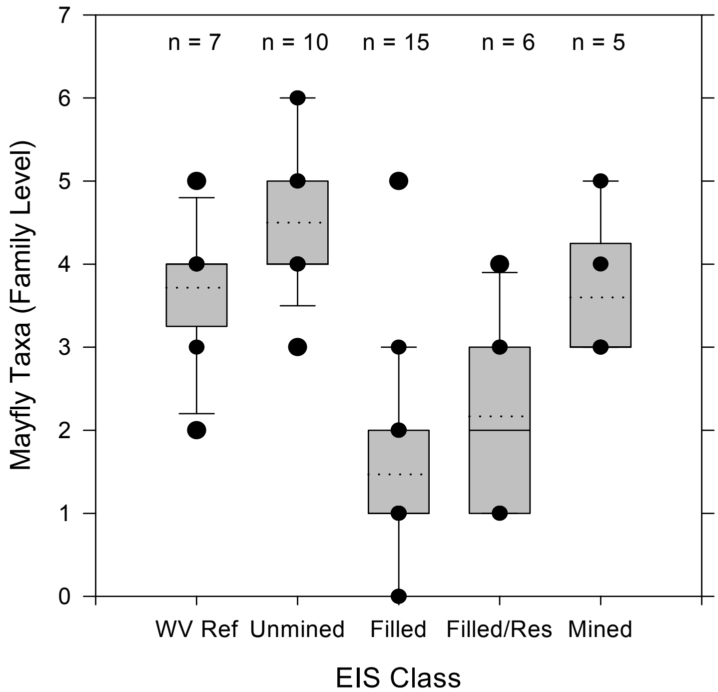


Figure 51. Comparison of %Mayfly Values
Spring 2000

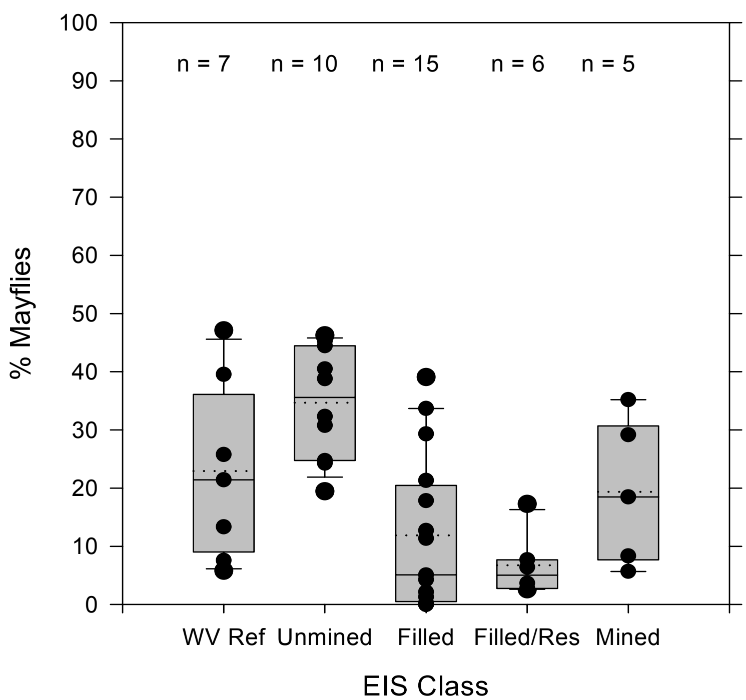


Figure 52. Comparison of % Chironomidae Values Spring 2000

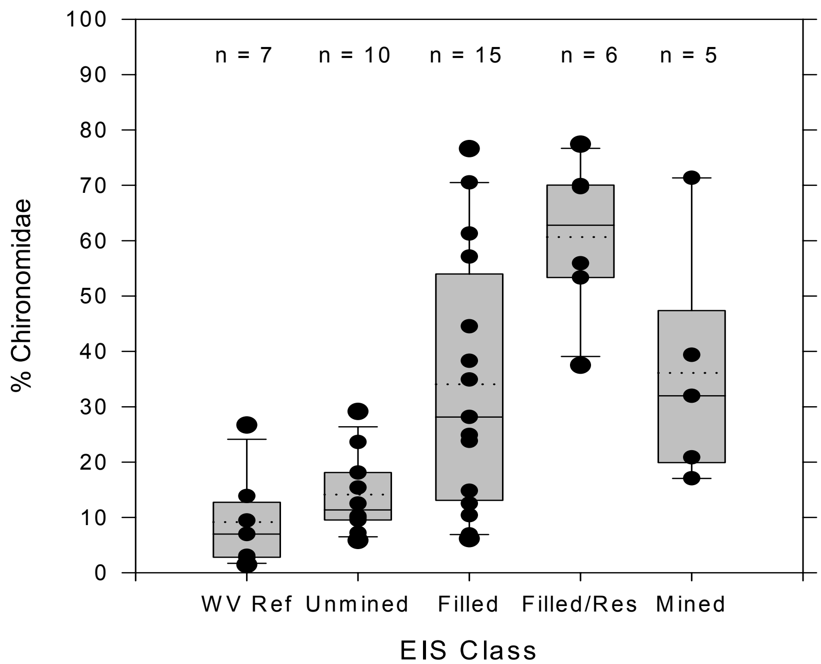


Figure 53. Comparison of Conductivity
Spring 1999

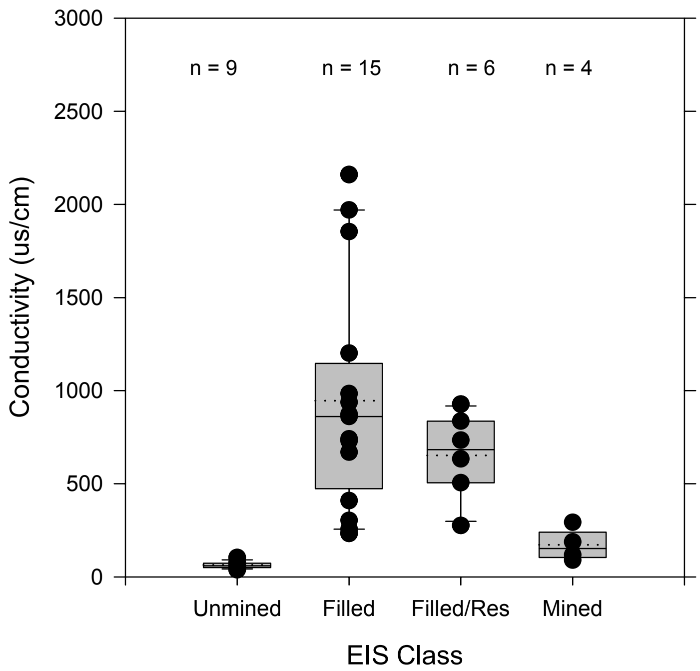


Figure 54. Comparison of pH
Spring 1999

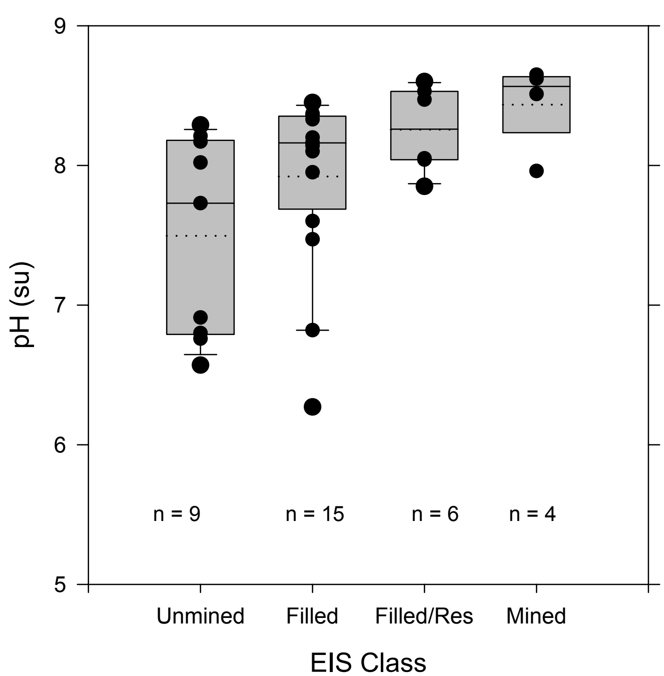


Figure 55. Comparison of Temperature
Spring 1999

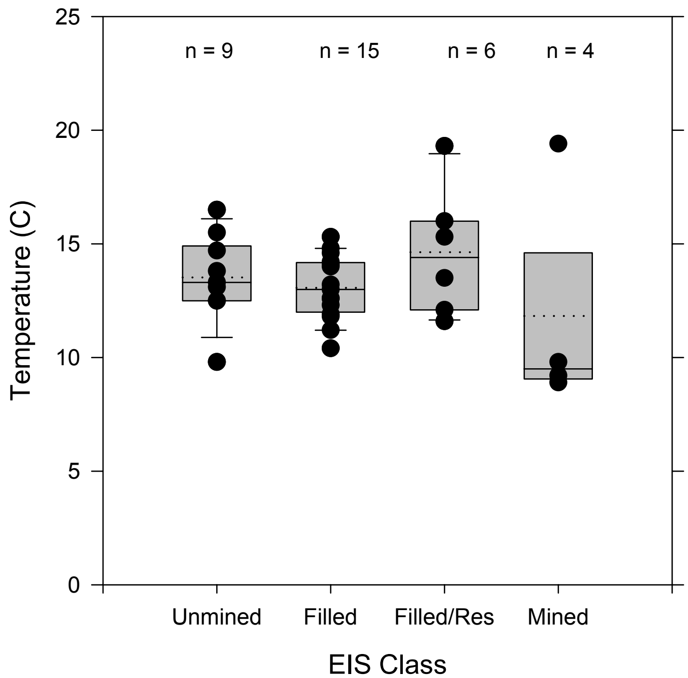


Figure 56. Comparison of Conductivity
Summer 1999

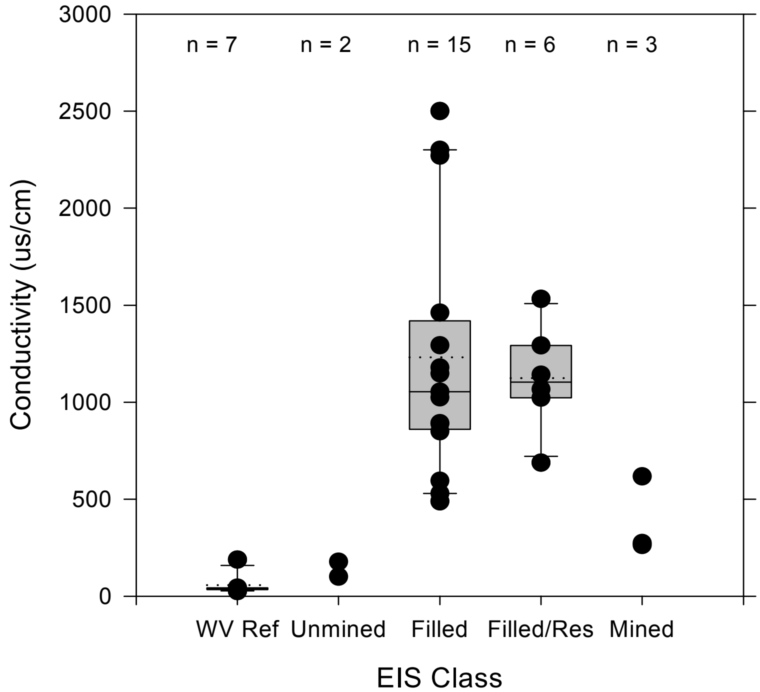


Figure 57. Comparison of pH
Summer 1999

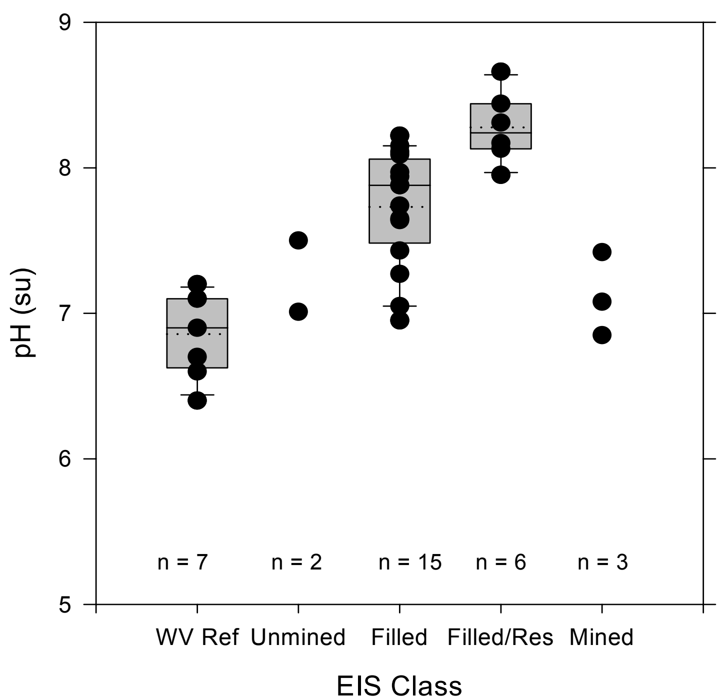


Figure 58. Comparison of Temperature
Summer 1999

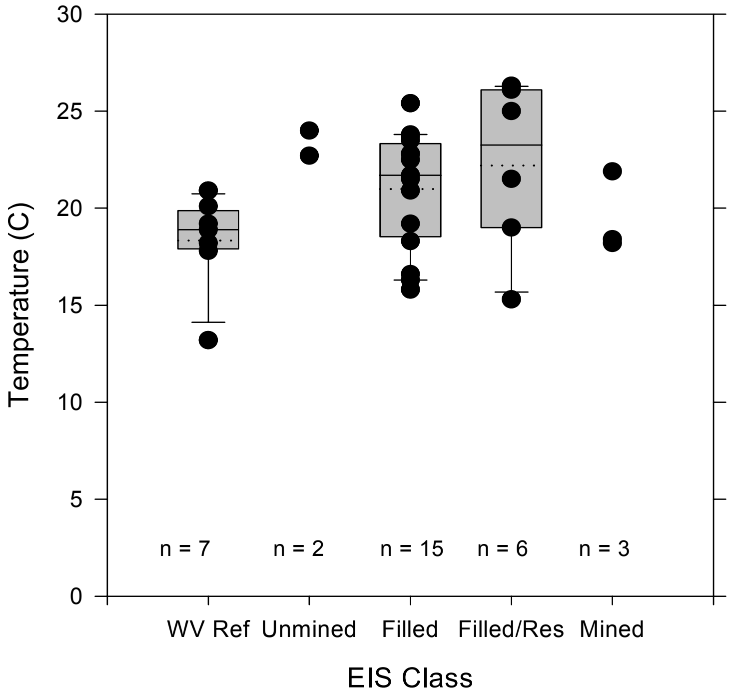


Figure 59. Comparison of Dissolved Oxygen (mg/l)
Summer 1999

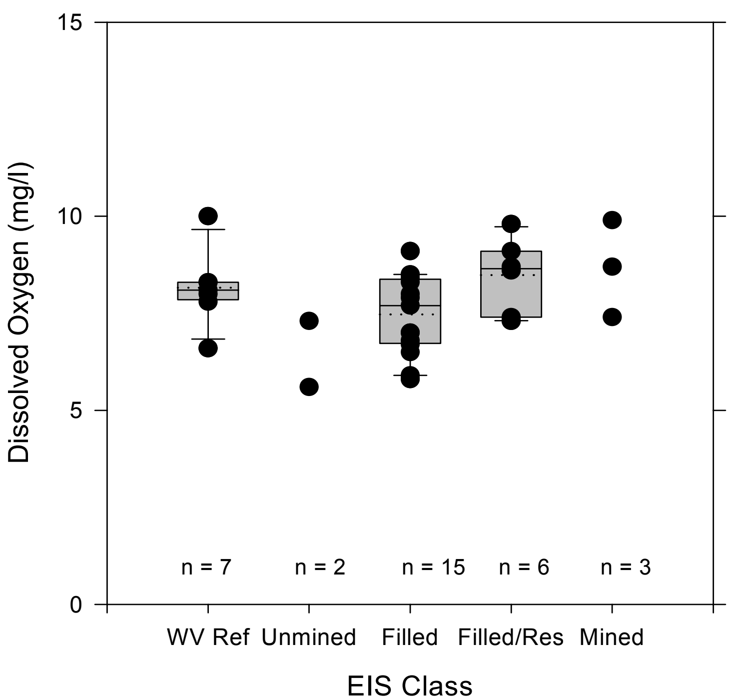


Figure 60. Comparison of Conductivity
Fall 1999

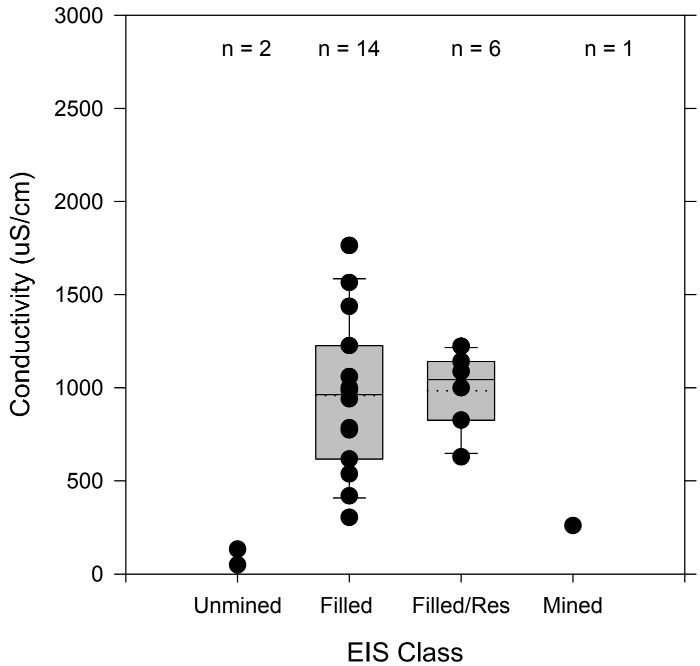


Figure 61. Comparison of pH
Fall 1999

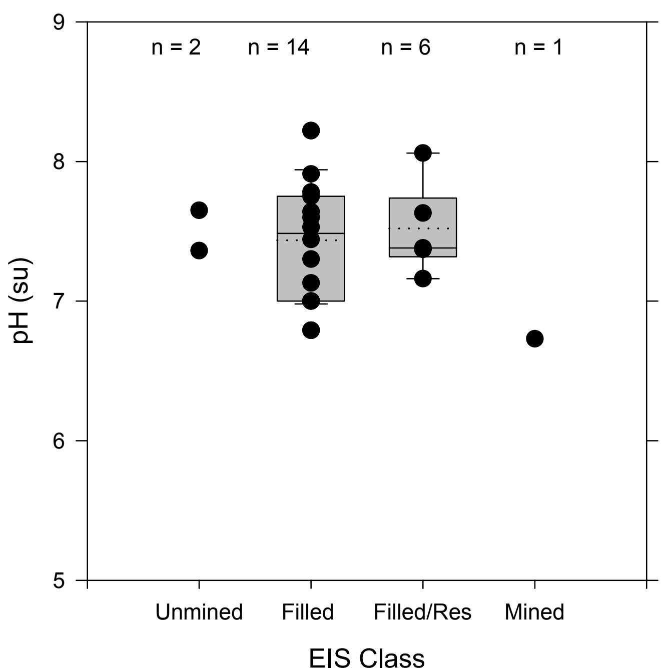


Figure 62. Comparison of Temperature
Fall 1999

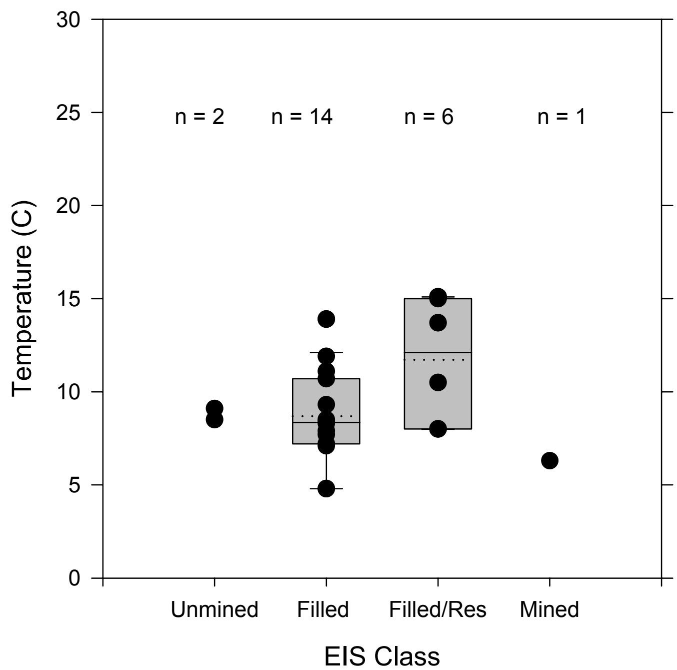


Figure 63. Comparison of Dissolved Oxygen
Fall 1999

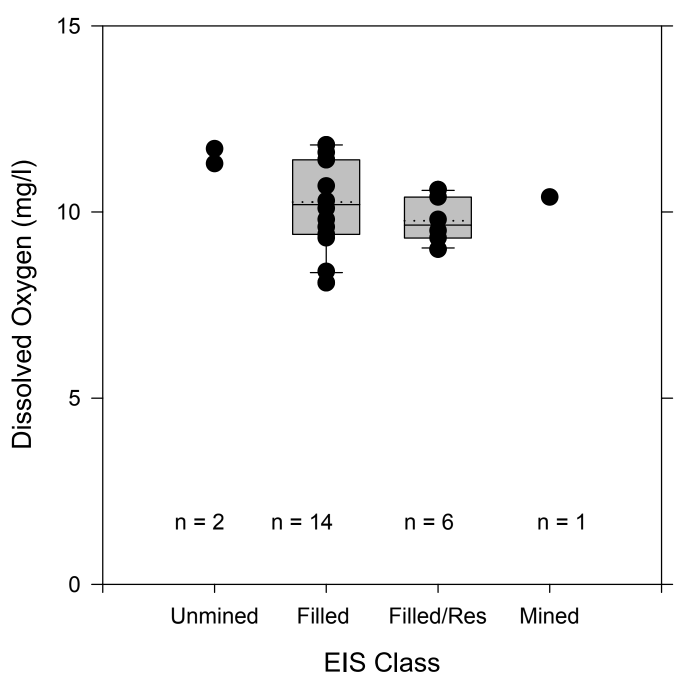


Figure 64. Comparison of Conductivity
Winter 2000

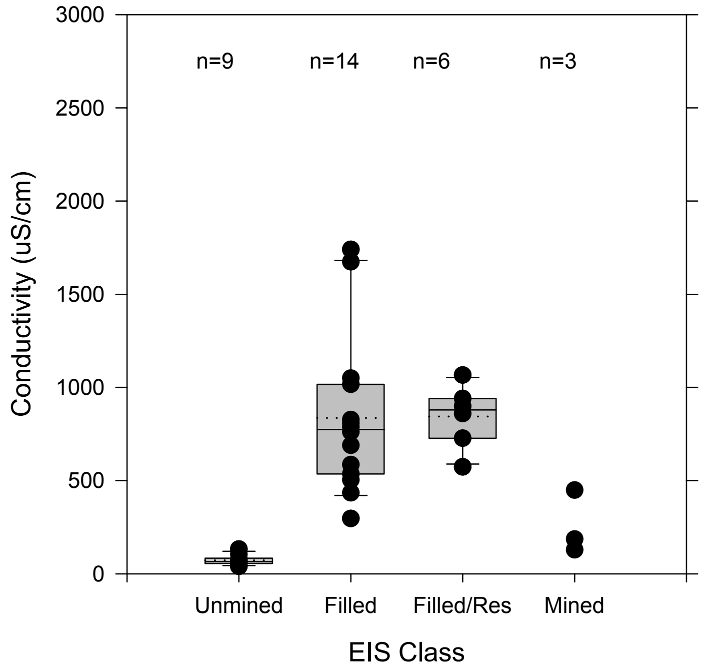


Figure 65. Comparison of pH
Winter 2000

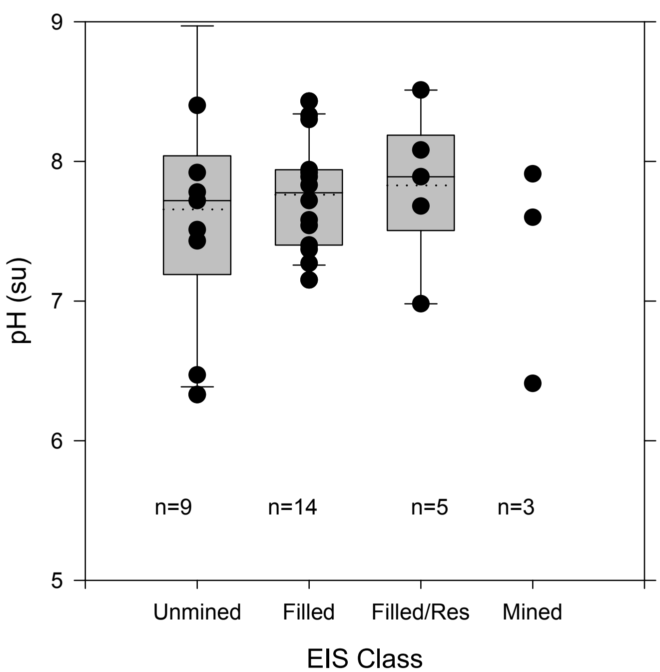


Figure 66. Comparison of Temperature
Winter 2000

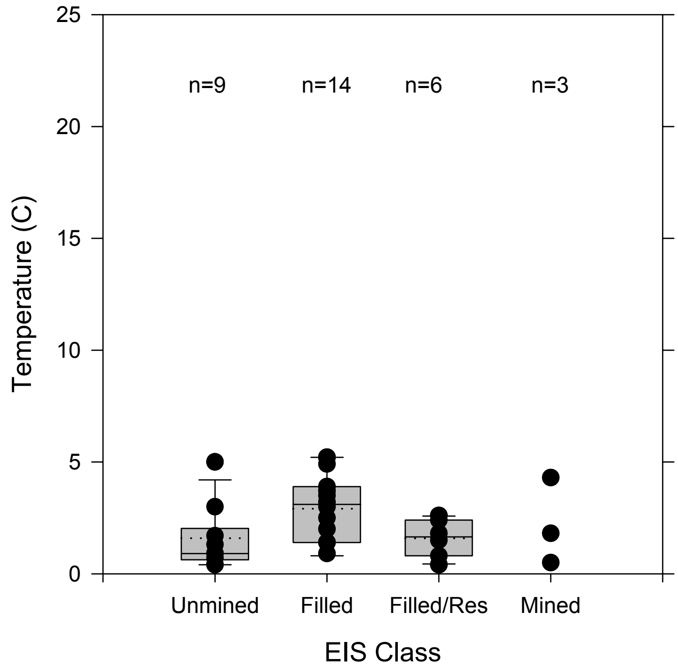


Figure 67. Comparison of Dissolved Oxygen
Winter 2000

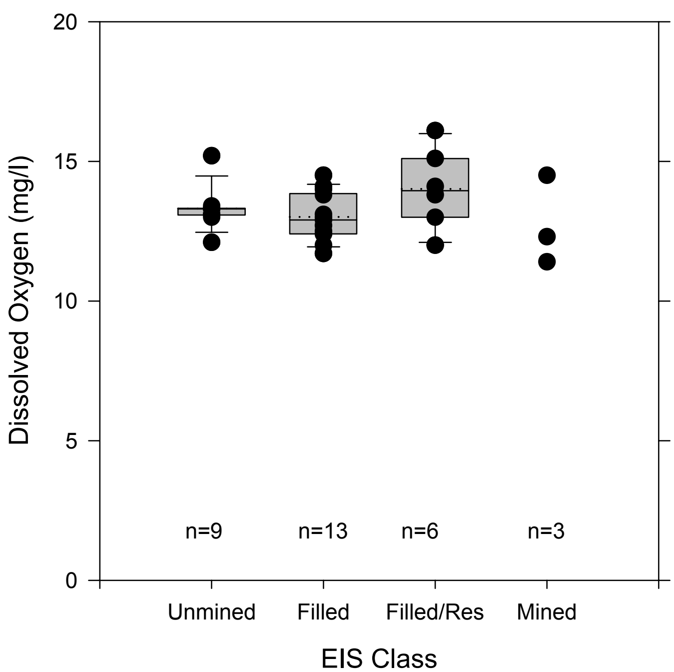


Figure 68. Comparison of Conductivity
Spring 2000

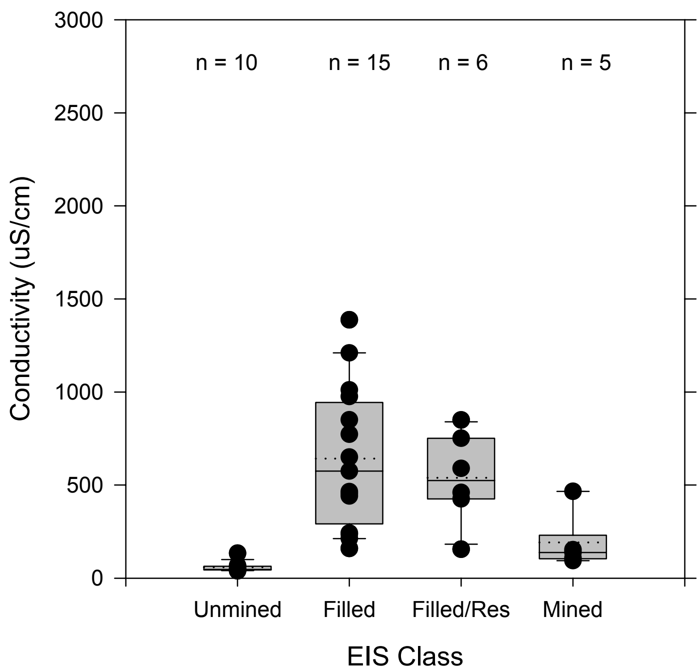


Figure 69. Comparison of pH
Spring 2000

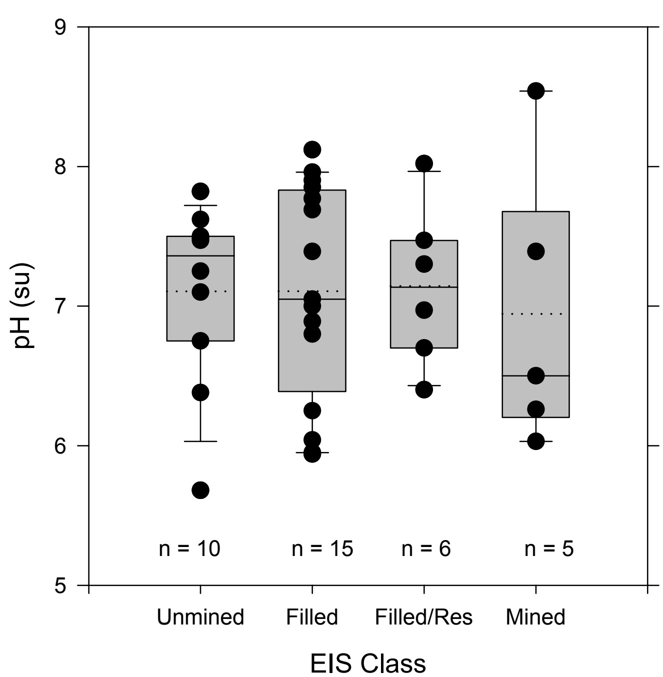


Figure 70. Comparison of Temperature
Spring 2000

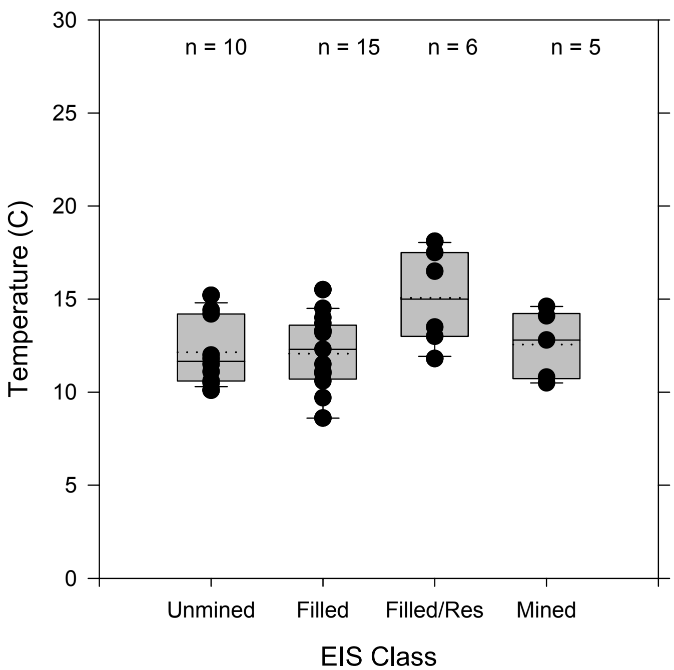


Figure 71. Comparison of Dissolved Oxygen
Spring 2000

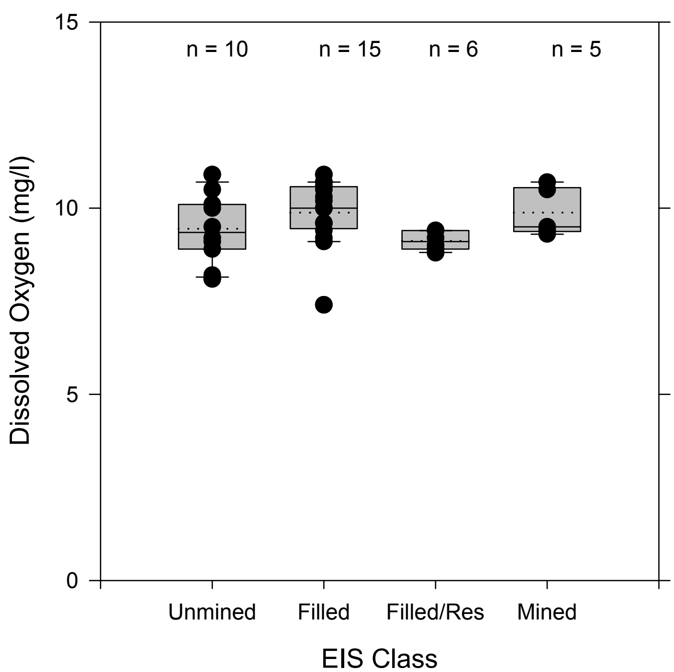


Figure 72. Rapid Habitat Assessment
Total Score
Spring 2000

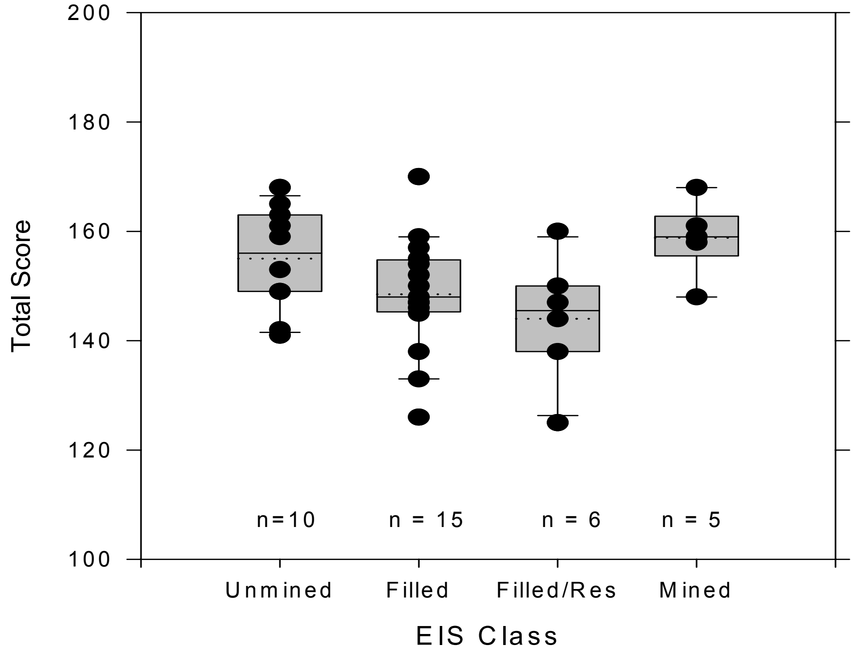


Figure 73. Rapid Habitat Assessment
Embeddedness Score
Spring 2000

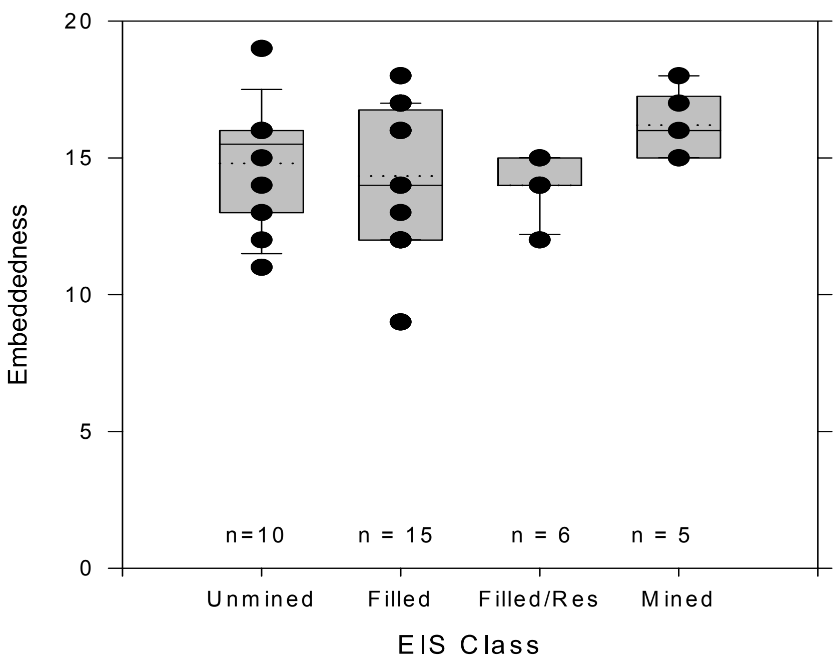


Figure 74. Rapid Habitat Assessment
Sediment Deposition Score
Spring 2000

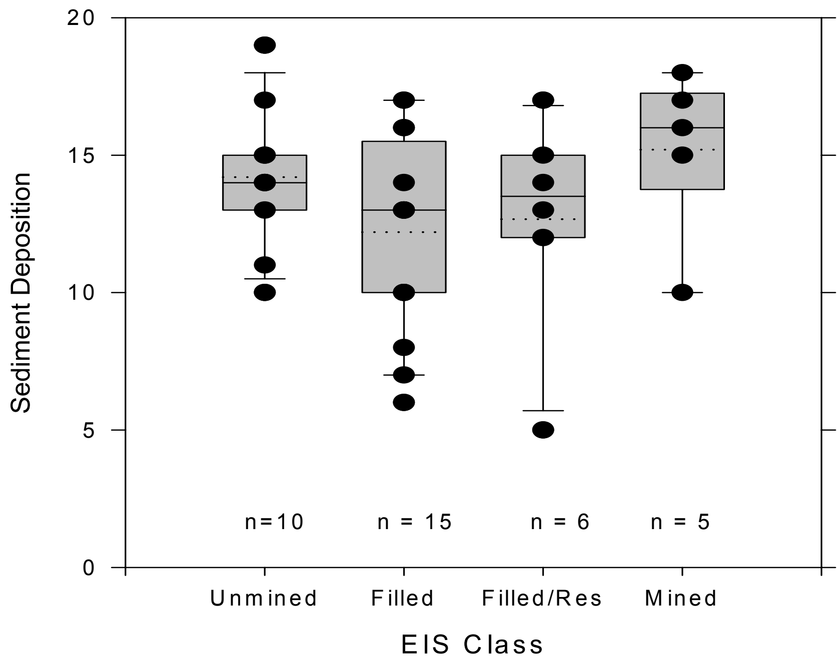


Figure 75. Rapid Habitat Assessment
Epifaunal Substrate Score
Spring 2000

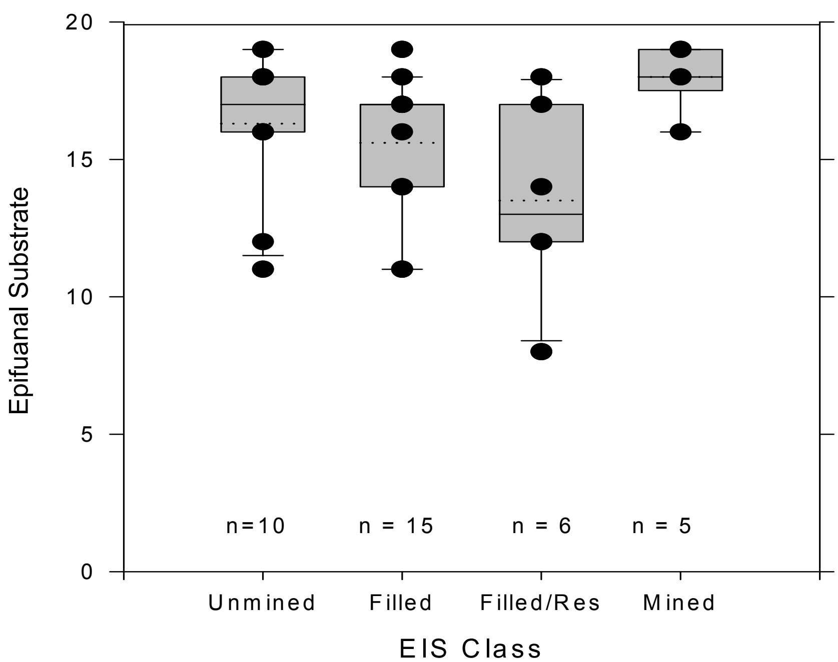


Figure 76. Rapid Habitat Assessment
Channel Flow Score
Spring 2000

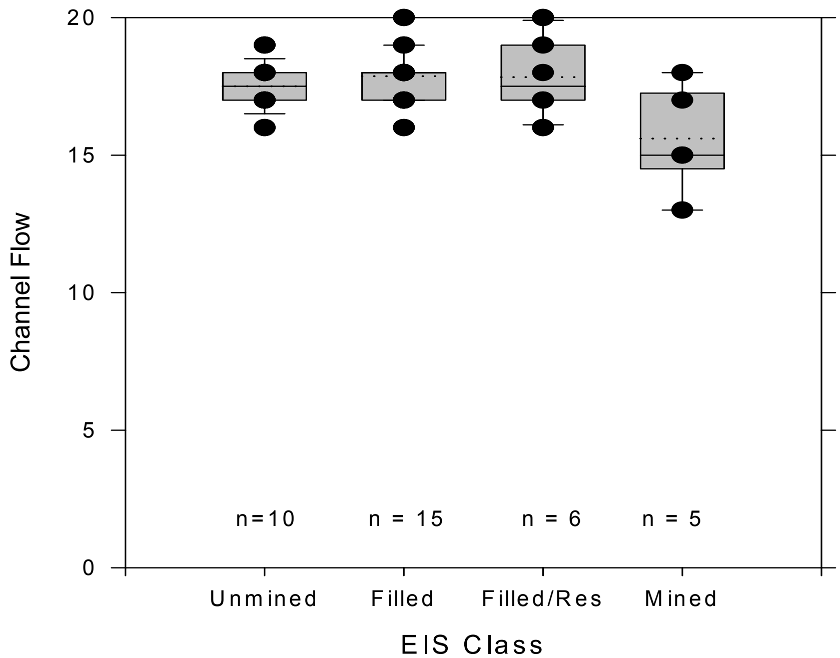


Figure 77. Rapid Habitat Assessment
Channel Alteration Score
Spring 2000

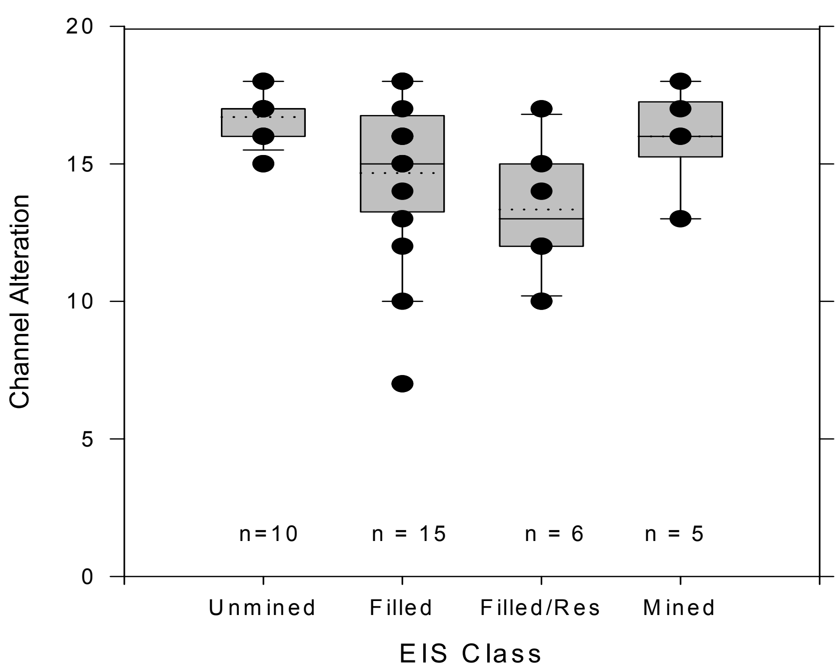


Figure 78. Rapid Habitat Assessment
Frequency of Riffles Score
Spring 2000

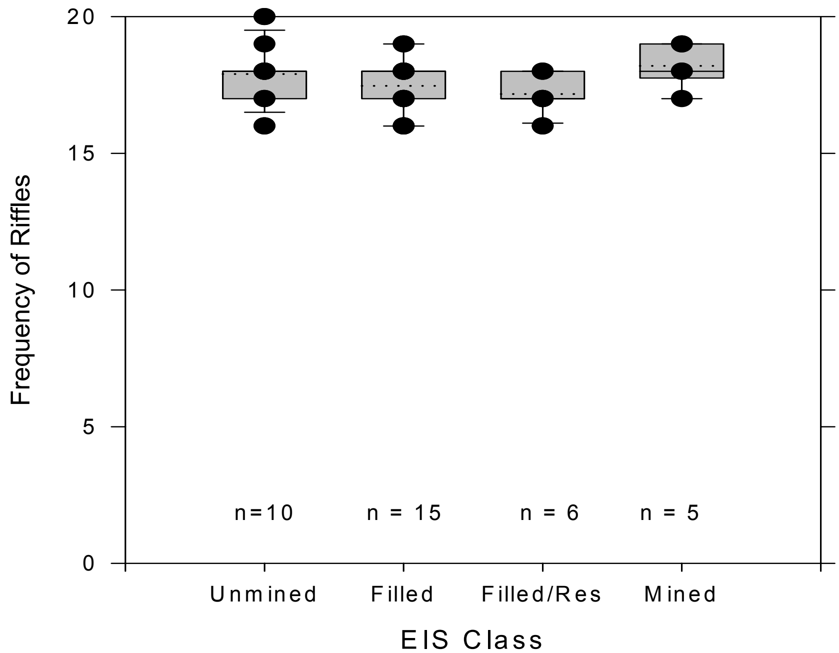


Figure 79. Rapid Habitat Assessment
Velocity Depth Combinations Score
Spring 2000

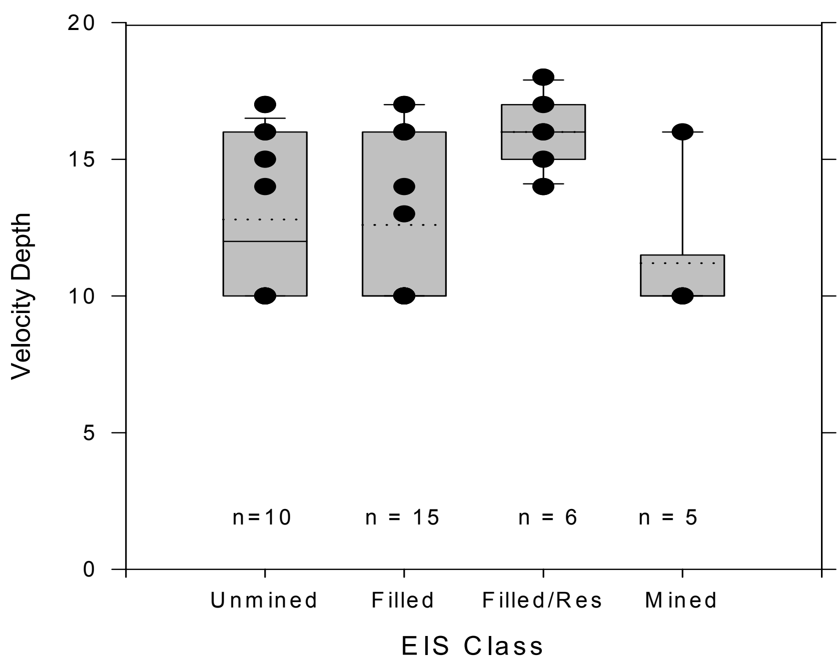


Figure 80. Rapid Habitat Assessment
Bank Stability Score
Spring 2000

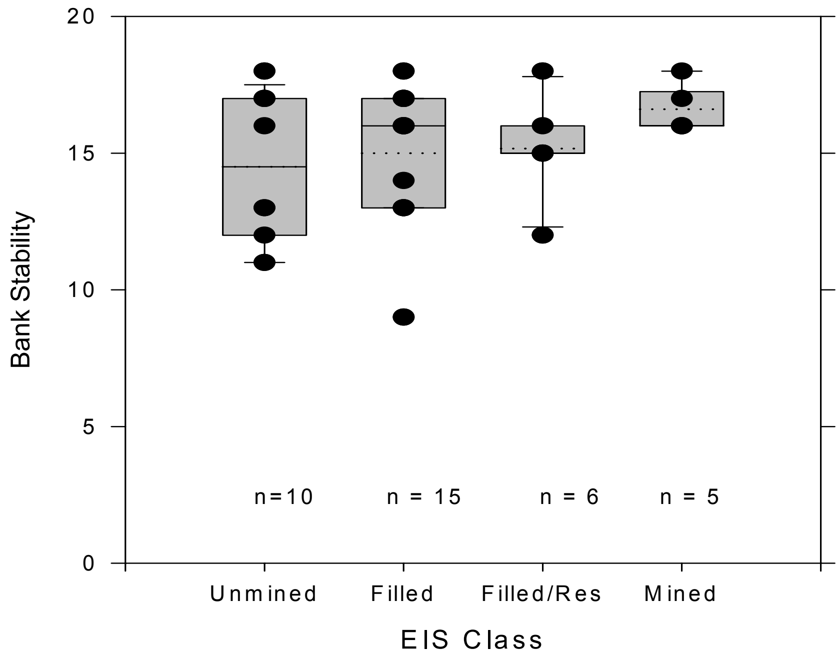


Figure 81. Rapid Habitat Assessment
Bank Vegetation Protection Score
Spring 2000

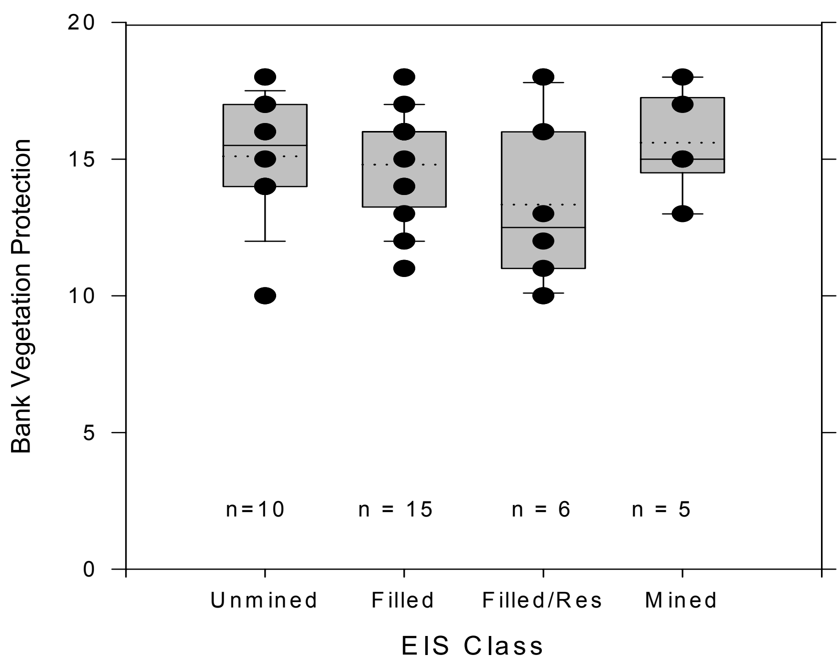


Figure 82. Rapid Habitat Assessment
Riparian Vegetation Zone Score
Spring 2000

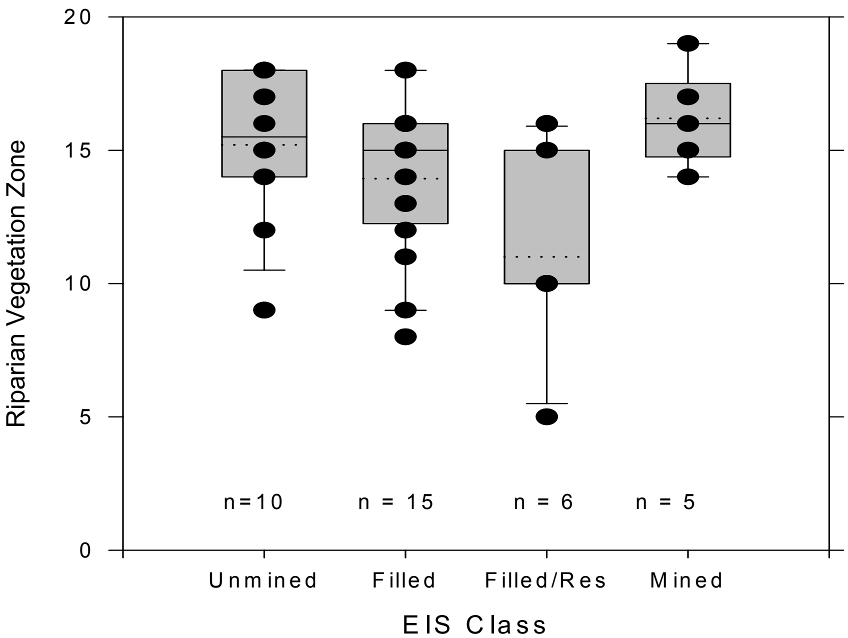


Figure 83. Mean Substrate Size Class

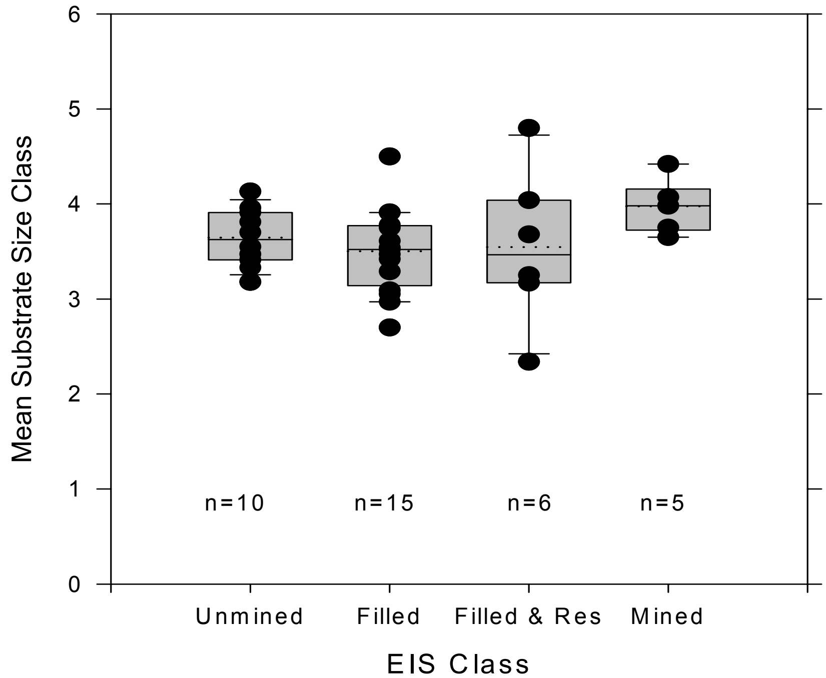


Figure 84. Estimated Geometric Mean Substrate Size

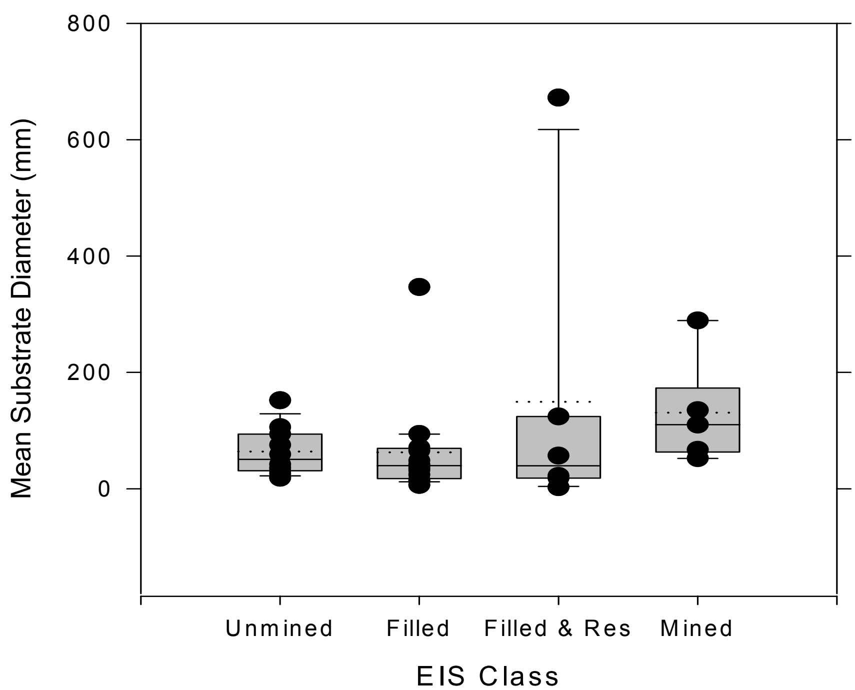


Figure 85. % of Substrate <=2mm (% that is sand and fines)

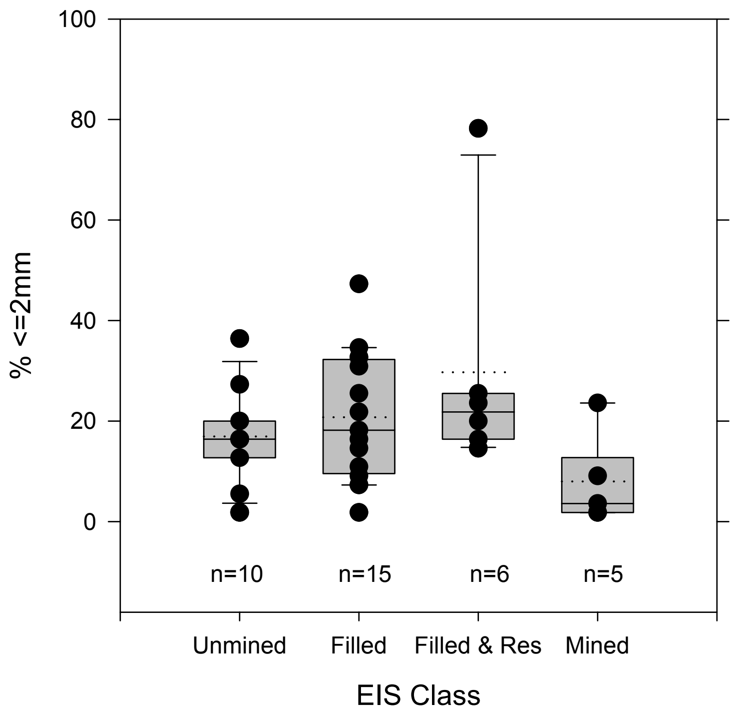


Figure 86. Relationship Between Stream Condition Index and Median Conductivity

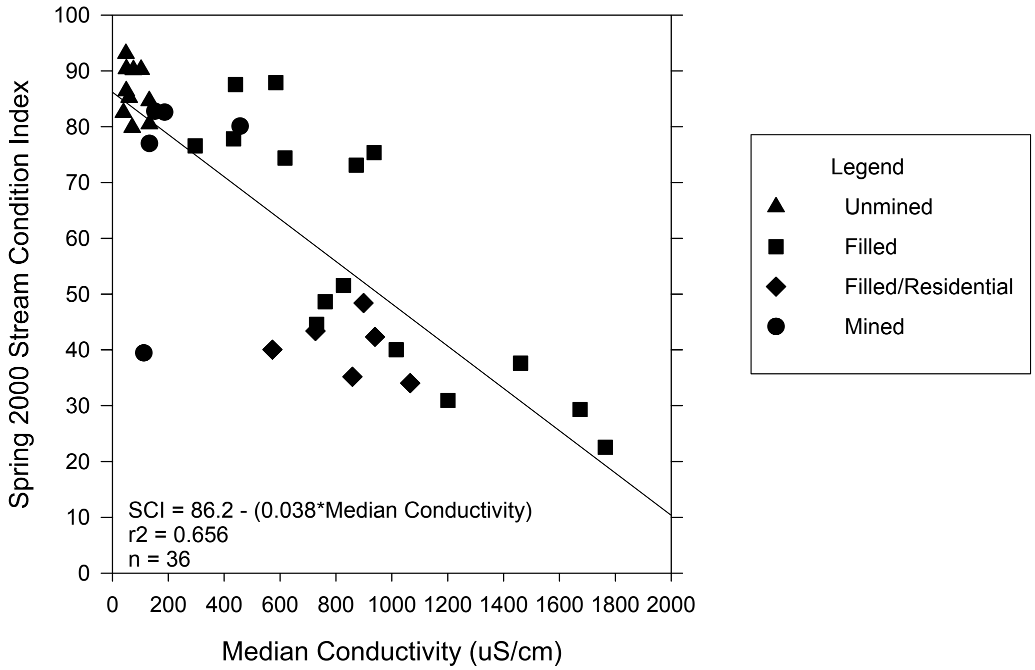


Figure 87. Relationship Between Stream Condition Index and log10(Median Conductivity)

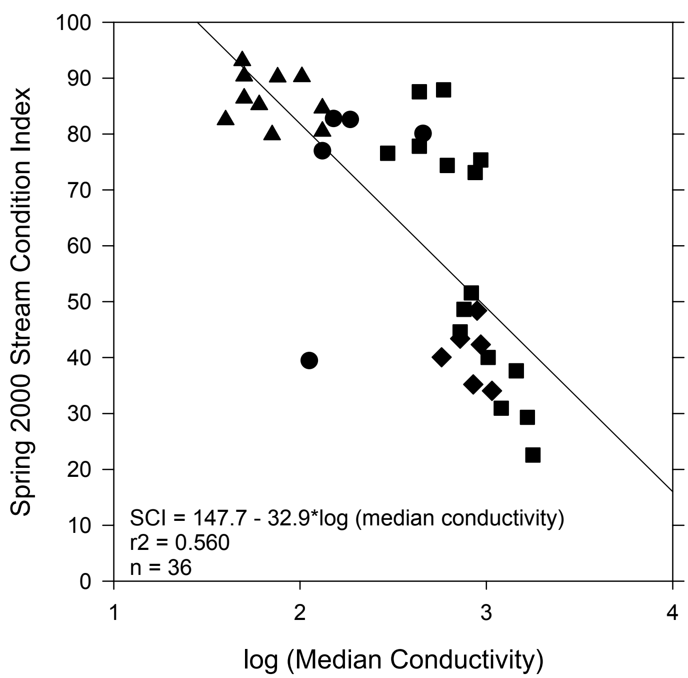


Figure 88. Relationship Between Stream Condition Index and Sediment Deposition Scores

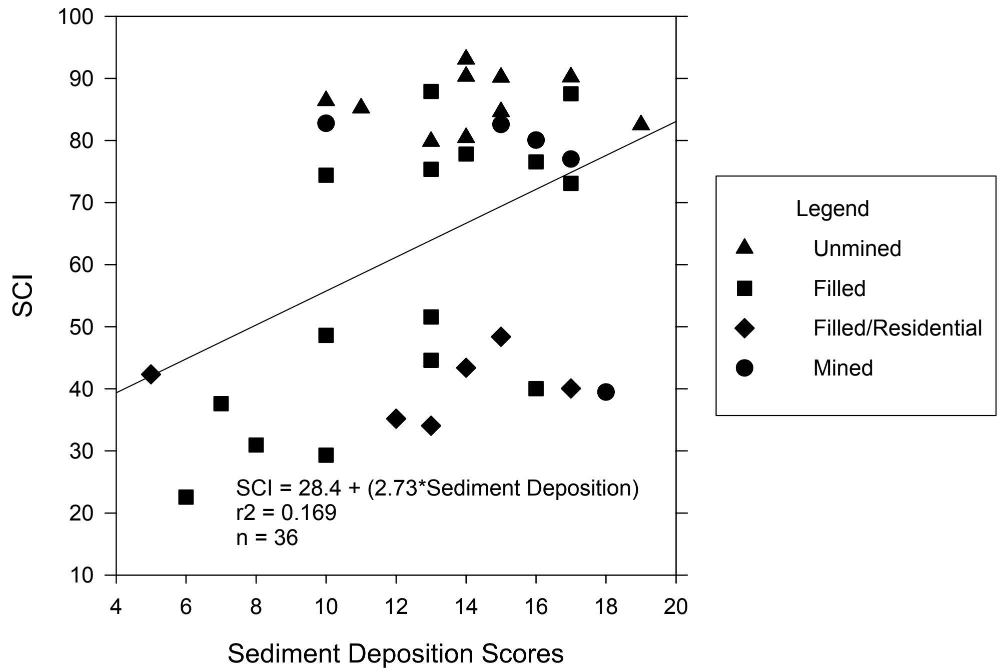


Figure 89. Relationship Between log10 (Stream Condition Index) and Sediment Deposition Scores

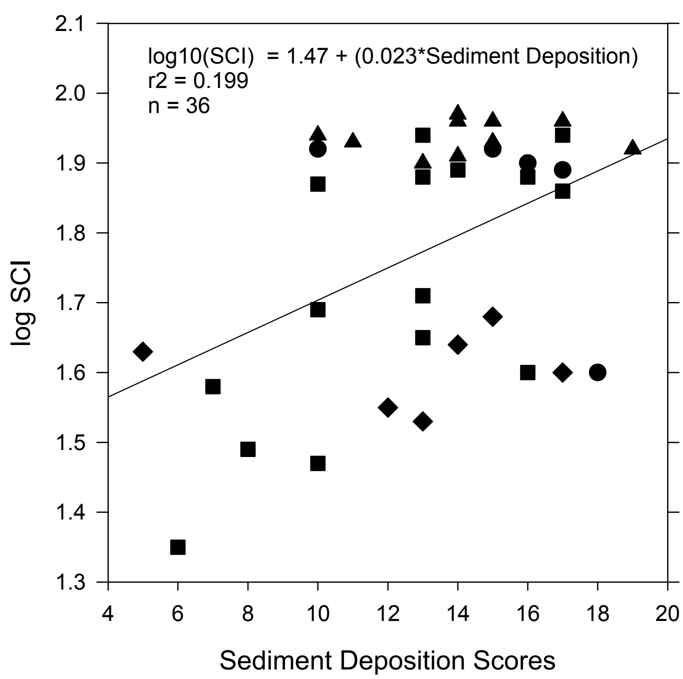


Figure 90. Relationship Between Stream Condition Index and Total Habitat Scores

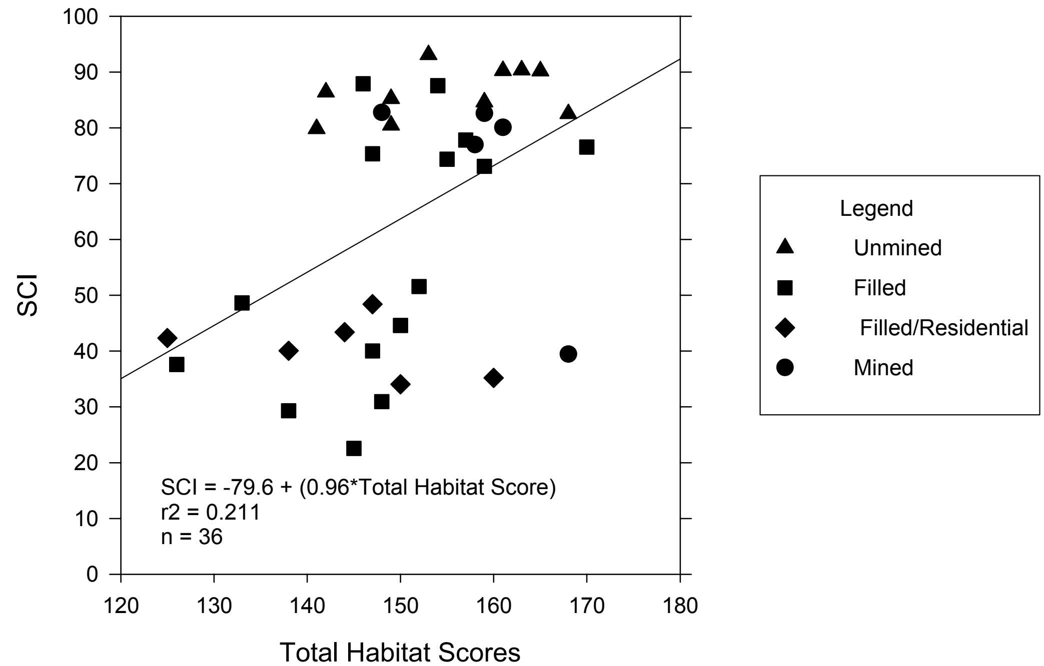
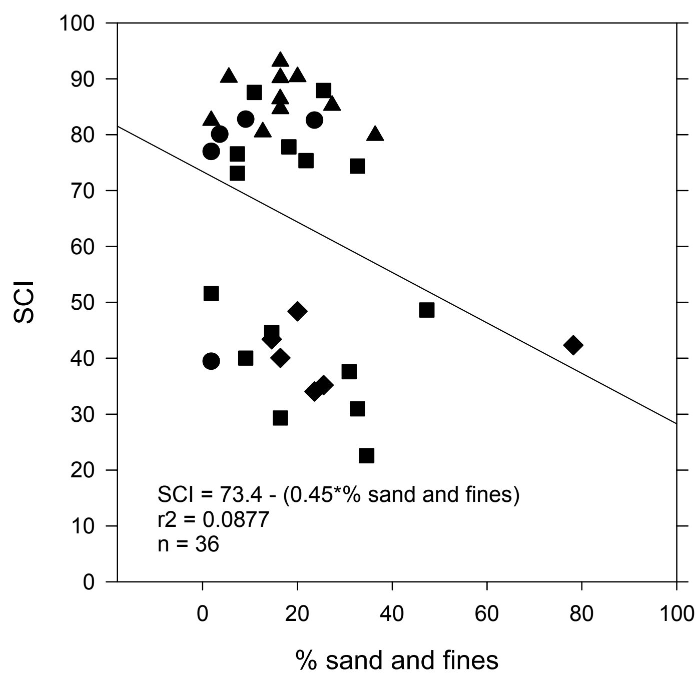


Figure 91. Relationship Between Stream Condition Index and % Sand and Fines



APPENDIX 5. REPLICATE DATA

Replicate samples were collected at the same place, at the same time, usually at adjacent locations in the same riffle. Replicates were collected in every season, at a total of 42 sites. Sites were chosen randomly and represent all classes and conditions of streams. The replicate samples provide an estimate of variability due to true spatial variation of the benthic assemblage within a site, and variation due to sampling and laboratory procedures. The replicate samples are highly correlated to each other for every metric used in this project (see table 4-1).

Replicate Sample Analysis Pearson Product Moment Correlation		
Metric	**Correlation Coefficient r**	**P value**
WVSCI	0.941	2.22E-20
Total Taxa	0.768	2.86E-9
EPT Taxa	0.798	2.48E-10
%EPT	0.921	6.24E-18
HBI	0.860	2.92E-13
% 2 Dominant	0.838	4.27E-12
%Chironomidae	0.902	3.74E-16
% Mayfly	0.967	2.61E-25
# Mayfly	0.831	9.83E-12

We also estimated the standard deviation of repeated measures, as suggested in the revised RBP protocol (Barbour et al 1999). The standard deviation was calculated as the root mean square error (RMSE) of an Analysis of Variance (ANOVA), where the sites are treatments in the ANOVA (see table below). These standard deviations can be used to estimate the detectable difference of a single sample from a threshold. Although comparing single samples to thresholds was not an objective of this study, the standard deviations do provide an estimate of the variability of our assessment technique.

Replicate Sample Analysis Statistics of Repeated Samples for the MTM/VF Region and the detectable difference at 0.1 significance level. Sampling Gear was a 0.5 meter wide, 595 um kick net. The WV SCI Score is on a 100 point scale. The data are at family level.		
Metric	**Standard Deviation for Repeated Measures (RMSE)**	**Detectable Difference for a single sample from a threshold (1-tailed test) (p=0.10)**
Total Taxa	2.2	2.8
EPT Taxa	1.6	2.0
HBI	0.42	0.54
% Two Dominant Taxa	5.7	7.3
% Chironomidae	6.6	8.4
% EPT	6.9	8.8
WV SCI	4.3	5.5
% Mayfly	3.2	4.1
# Mayfly Taxa	0.7	0.9

APPENDIX 6. DOCUMENTATION OF THE DROUGHT

The region of MTM/VF coal mining in WV suffered periods of prolonged dryness and drought in 1998 and 1999. West Virginia was relatively dry in July and August of 1998. Although rains occurred in September, soil moisture levels remained low. By September 1998, the National Drought Mitigation Center (NDMC) classified the state as an area to watch as far as drought concern (NDMC 1998). Stream flows remained normal throughout July and August, but were below normal in September (USGS 1998). There was not enough rainfall in October or November to improve soil moistures. In November, the state received only 45% of its normal rainfall (NDMC 1999a). The NDMC classified WV as "experiencing dryness" during October and as "experiencing significant dryness" for November and December (NDMC 1998). In December the USGS reported below normal stream flows October, November, and December (USGS 1999). By the end of December, southern portions of the state received temporary relief in the form of above normal amounts of precipitation (NDMC 1999a).

During the first month of 1999, WV received 167% of normal precipitation, but additional moisture was needed to overcome long-term shortages (NDMC 1999a). Stream flows in January were normal for southern and eastern portions of the state and were above normal for northern areas. Stream flows were reported as below normal for most of the state during February, but were reported as normal during March 1999 (USGS 1999). Stream flows for April are of particular interest since the first round of USEPA MTM biological samples were collected during April and early May. Unfortunately the USGS National Water Conditions' stream flow map for April 1999 was absent from the USGS National Water Conditions Internet site.

Rainfall amounts, for most of WV, were below normal in May, June, and July of 1999 (NDMC 1999b). The NDMC classified all of WV as an "area to watch" in May, an "area experiencing significant dryness" for June, and a "state or federally declared drought" for July, August, and September of 1999 (NDMC 1999a). USGS stream flows for the entire state, were below normal for the entire state during May, June, and July (USGS 1999). USEPA MTM biological samples were collected from July 26 – August 11. The Palmer Index of drought severity described the climate divisions that included the sampling sites as "severe drought" during these weeks. The NDMC pulled the following statement from the National Weather Service's WV Drought Statement from July 29, 1999: "The USGS reports that 80% of the river gages that have a 30 or more year record are below-normal flow for this time of year. . . Many small streams remain dry or flowing at a trickle. . . Most farm ponds remained very low or nearly dry" (NDMC 1999a).

The southwestern portion of WV continued to be classified as experiencing a drought by the US drought monitor in October, November, and December 1999 (NDMC 1999b). Most of the USGS gauges in WV continued to record below average flows during August, September, and November. Gages in the region of major mountaintop mining (MTM) activity in WV (Fedorko and Blake 1998) continued to have below average stream flows during December 1999 (USGS 1999).

On January 12, 2000 the National Weather Service (NWS) reported that drought conditions had eased for much of WV, southeast OH, eastern KY, and southwest VA. The NWS described a decrease in rainfall deficits and indicated that the Palmer Index classified the same area at normal conditions. Only 20% of the river gages in WV were reporting below normal flow, but groundwater levels were still a concern (NWS Charleston, WV 2000). Gages in the MTM region in WV continued to have below average stream flows during January, but USGS reported normal stream flows for all gages in WV during February (USGS 2000).

Throughout Spring 2000 stream flows fluctuated between normal and below normal. The USGS reported below normal stream flow for most of WV during March and May and reported normal stream flow during April and June (USGS 2000). The Long-term Palmer Index calculations for April 1, April 11, and May 13 suggested that eastern portions of the MTM region in WV were experiencing moderate drought conditions. However, the index suggested that conditions were near normal on April, 8, April 22, April 29, and May 6 (CPC 2000). The U.S. Drought Monitor continued to classify all or portions of the MTM region as "abnormally dry" throughout Spring 2000. This abnormally dry classification is used to describe areas "going into drought: short-term dryness slowing planting and growing crops or pastures; fire risk above average" and areas that are, "Coming out of drought: lingering water deficits; pastures or crops not fully recovered" (U.S. Drought Monitor 2000). Similarly, the National Drought Mitigation Center continued to classify southwestern WV as either a "drought watch area" or as an area "recovering from drought, but should be monitored closely for recurring conditions or lingering impacts" from February through May (NDMC 2000).

It is important to acknowledge that most of the drought data available at this time has been released as provisional data subject to review and that the data are aggregated spatially and temporally. In some cases the areal units are larger than the region of mountaintop mining activity in WV. However, the drought seems to have impacted a large region over several months rather than isolated locations and times. Different aggregations of the data are likely to show the same trends.